VOLUNTARY CLEANUP AND REDEVELOPMENT ACT APPLICATION FOR GRAND VIEW SMELTER SITE RICO, COLORADO

Submitted to:

COLORADO DEPARTMENT OF PUBLIC HEALTH AND ENVIRONMENT

Submitted by:

Atlantic Richfield Company
Rico Properties, L.L.C.

April 1996

Table of Contents

GRAND VIEW SMELTER
TABLE OF CONTENTS

TABLE OF CONTENTS CONT'D

TABLE OF CONTENTS CONT'D

TABLE OF CONTENTS CONT'D

FIGURES **(follows page)**

TABLE OF CONTENTS CONT'D

TABLE OF CONTENTS CONT'D

VOLUNTARY CLEANUP AND REDEVELOPMENT ACT APPLICATION

July 11, 1994 Draft

This application form is prepared by the Colorado Department of Public Health and Environment, to assist potential applicants in meeting the requirements outlined in the Voluntary Cleanup and Redevelopment Act (HB94-1299). Adherence to this application will insure that adequate information is submitted to allow the Department to evaluate the application and make a determination on the Voluntary Cleanup Plan or No Action Petition. All applications must include a filing fee of $2000. Department review time will be billed against this fee, with any remaining funds to be returned to the applicant.

GENERAL INFORMATION

The applicant should begin by providing the following general information:

Page

1-2 1) Name and address of owner
1-2 2) Contact person and phone number
1-1 3) Location of property
1-2 4) The type and source of contamination
1-2 5) If contamination will remain on property following implementation of your proposal, provide Global positioning system coordinates
1-2 6) State whether request is for approval of Voluntary Cleanup Plan (VCUP) or a petition of No Further Action Determination (NAD)
1-2 7) Current Land Use
1-2 8) Proposed Land Use

PROGRAM INCLUSION

This section is designed to determine whether the applicant meets the criteria for eligibility under the Act. Please answer yes (Y), no (N), or not sure (NS) to the questions below. If the answer to any of the questions is not sure (NS) please fill out the appropriate checklist questionnaire in Appendix 1 (these have not yet been developed at the time of the last draft). An answer "no" to question 1 or "yes" to questions 2-6 will result in a determination that the application is not eligible for the Voluntary Cleanup Program. The submission of misleading information will render any approval given by the Department void.

Page

1-3 1) Is the applicant the owner of the property for the submitted VCUP or NAD? IF yes, verify ownership.
Yes

1-3 2) Is the property submitted for the VCUP or NAD listed or proposed for listing on the National Priorities
No List of Superfund sites established under the federal act (CERCLA)

1-3 3) Is the property submitted for which the VCUP or NAD the subject of corrective action under orders or
No agreements issued pursuant to the provisions of Part 3 of Article 15 of this Title or the federal "Resources Conservation and Recovery Action of 1976", as amended? If yes, please list order number.

1-3 4) Is the property submitted for the VCUP or NAD subject to an order issued by or an agreement (including
No permits) with the Water Quality Control Division pursuant to Part 6 of Article 8 of this Title? If yes, please list order or permit number.

1-3 5) Is the property submitted for the VCUP or NAD a facility which has or should have a permit or interim
No status pursuant to Part 3 of Article 15 of this Title (RCRA Subtitle C) for treatment, storage, or disposal of hazardous waste? IF yes, please list permit number.

NOTE: Properties that do not have a permit or interim status but at which hazardous waste, as defined in the Colorado Hazardous Waste Act and implementing regulations, was treated, stored, or disposed of at any time after 1980 is considered by the Department to have required a permit or interim status. Disposal is defined as any discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water so that such solid waste or hazardous waste or any constituent thereof may enter the environment.

1-3 6) Is the property submitted for the VCUP or NAD subject to the provisions of Part 5 of Article 20 of Title
No 8 (Underground Storage Tank - State Oil Inspector), C.R.S. or of Article 18 of this Title (RCRA subtitle I).

VOLUNTARY CLEANUP APPLICATION

Any plan for voluntary cleanup (VCUP) or request for no action determination (NAD) must include the following information to be considered complete. Applicants need to supply enough information in sufficient detail for the Department to make a determination. If certain information is not applicable to the site, the applicant may provide evidence and explanations as to why specifically requested information is not applicable. It is most important that the applicant describe the rationale used in performing the site investigation (including selection of sampling locations and parameters), performing risk assessments, selecting cleanup levels, and any other decision making process included in the application.

The applicant should include a cross reference listing the page number(s) of the application which correspond to the following listed information requirements on the blank line to the left of the information description on this form (or by other equivalent means).

ENVIRONMENTAL ASSESSMENT

Page

2-1 1) Environmental assessments must be submitted by qualified professionals, who are defined as persons having education, training, and experience in preparing environmental studies and assessments. The applicant should submit documentation, in the form of a statement of qualifications or resume, that the environmental assessment has been prepared by a qualified environmental professional.

1-1 2) The applicant should provide the address (if applicable) and legal description of the site, and a map of appropriate scale identifying the location and size of the property.

2-3&2-7 3) The applicant should describe the operational history of the property in detail, including the most current use for the property. This description should include, but not be limited to:

2-3&2-7 (i) a description of all business/activities that occupy or occupied the site as far back as records/knowledge allows;

2-3&2-7 (ii) a brief description of all operations which may have resulted in the release of hazardous substances or petroleum products at the site both past and present, including the dates activities occurred at the property, and dates during which contaminants were released into the environment;

2-8 (iii) a list of all:

(a) site specific notifications made as a result of any management activities of hazardous substances conducted at the site, including any and all EPA ID numbers obtained for management of hazardous substances at the site from either the State or the U.S. Environmental Protection Agency (EPA):

2-8 (b) notification to county emergency response personnel for the storage of reportable quantities of hazardous substances required under Emergency Planning and Community Right to Know statutes; and

2-8 (c) notifications made to State and/or Federal agencies as a reporting spills and/or accidental releases, including notifications to the State Oil Inspection Section required under 8-20-506 and 507 and 25-18-104 C.R.S. 1989 as amended, and 6 C.C.R.1007-5 Subpart 28.50. Part 3 of the OIS regulations etc.;

2-8 (iv) a list of all known hazardous substances used at the site, with volume estimates;

2-8 (v) a list of all wastes generated by current activities conducted at the site, and manifests for shipment of hazardous wastes off-site;

2-8 (vi) a list of all permits obtained from State or Federal agencies required as a result of the activities conducted at the site; and

2-7 (vii) a brief description of the current land uses, zoning and zoning restrictions of all areas contiguous to the site.

2-9 4) The applicant shall describe the physical characteristics of the site, including a map to scale (or separate maps, whichever represent the following types of information most clearly), and an accompanying narrative showing and describing the following (where applicable):

2-9 (i) topography;
2-10 (ii) all surface water bodies and wastewater discharge points;
2-11,2-28 (iii) ground water monitoring & supply wells;
2-26 (iv) facility process units and loading docks;
2-26 (v) chemical and/or fuel transfer, and pumping stations;
2-26 (vi) railroad tracks and rail car loading areas;
2-26 (vii) spill collection sumps and/or drainage collection areas;
2-26 (viii) wastewater treatment units;
2-26 (ix) surface and storm water run-off retention ponds and discharge points;
2-26 (x) building drainage or wastewater discharge points;
2-26 (xi) all above or below ground storage tanks;
2-26 (xii) underground or above ground piping;
2-26 (xiii) air emission control scrubber or refrigeration units;
2-26 (xiv) water cooling systems or refrigeration units;
2-26 (xv) sewer lines;
2-26 (xvi) french drain systems;
2-26 (xvii) water recovery sumps and building foundations;
2-26 (xviii) surface impoundments;
2-26 (xix) waste storage and/or disposal areas/pits, landfills etc.;
2-26 (xx) chemical or product storage areas;
2-26 (xxi) leach fields; and
2-26 (xxii) dry wells or waste disposal sumps.

2-28	5) If groundwater contamination exists, or if the release has the potential to impact groundwater, the applicant should provide the following information for areas within one-half mile radius of the site:
2-28	(i) the State Engineer's Office listing of all wells within the one-half mile radius of the site, together with a map to scale showing the locations of these wells;
2-28	(ii) documentation of due diligence in verifying the presence or absence of unregistered wells supplying ground water for domestic use in older residential neighborhoods, or in rural areas;
Not Applicable	(iii) a statement about each well within the half-mile radius of the site, stating whether the well is used as a water-supply well, or a ground water monitoring well;
Not Applicable	(iv) lithologic logs for all on-site wells;
Not Applicable	(v) well construction diagrams for all on-site wells, showing screened interval, casing type and construction details (obtainable from the State Engineer's Office), including: gravel pack interval, bentonite seal thickness and cemented interval;
2-28	(vi) a description of the current and proposed uses of on-site groundwater in sufficient detail to evaluate human health and environmental risk pathways. In addition, the applicant will provide a discussion of any State and/or local laws that would restrict the use of on-site ground water.
2-21,2-25 2-28	7) The applicant should provide information concerning the nature and extent of any contamination and releases of hazardous substances or petroleum products which have occurred at the site, including by not limited to:
2-28	(i) identification of the nature and extent, both on-site and off-site, of contamination that has been released into soil, ground water and surface water at the property, and/or releases of substances from each of the areas identified in Section 25-16-308(b) above;
2-28,2-34	(ii) a determination of whether or not, those substances identified in paragraph (i) above, contain hazardous substances either through process knowledge, Material Safety Data Sheet information provided by a manufacturer, or through chemical analysis;
2-28,2-34	(iii) a statement defining the chemical nature, mobility and toxicity of the substances identified in paragraph (i) above, estimated volumes and concentrations of substances discharged at each area, discharge point, drain, or leakage point;
Not Available	(iv) a map to scale showing the depth to ground water across the site;
Not Available	(v) a map to scale showing the direction and rate of ground water movement across the site using a minimum of three (3) measuring points;
None	(vi) a discussion of all hydraulic tests performed at the site to characterize the hydrogeologic properties of any aquifers on-site and in the area;
2-28	(vii) all reports and/or correspondence which detail site soil, ground water and/or surface water conditions at the site, including original analytical laboratory reports for all samples and analyses;
Separate Reports Provided	(viii) a discussion of how all environmental samples were collected, including rationale involved in sampling locations, parameters, and methodology, a description of sampling locations, sampling methodology and analytical methodology, and information on well construction details and lithologic

logs. All sample analyses performed and presented as part of the environmental assessment should be appropriate and sufficient to fully characterize all constituents of all contamination which may have impacted soil, air, surface water and/or ground water on the property. The applicant should use EPA approved analytical methods when characterizing the soil, air, surface water and/or ground water.

APPLICABLE STANDARDS/RISK DETERMINATION

3-1 1) The applicant should provide a description of applicable promulgated state standards establishing acceptable concentrations of constituents (present at the site) in soils, surface water, or ground water.

3-7 2) The applicant should provide a description of the human and environmental exposure to contamination at the site based on the property's current use and any future use proposed by the property owner. This description shall include, but not be limited to the following:

3-7 (i) a table or list, for site contaminants indicating:

Not Applicable (a) whether they are known to be carcinogenic (together with any relevant toxicity information for each carcinogenic contaminant available, including the slope factor for the contaminant) or whether they are non-carcinogenic (together with any relevant toxicity information on each contaminant, including reference doses if available);

3-7 (b) which media (i.e., soil, sir surface water and ground water) are contaminated, and the estimated vertical and areal extent of contamination in each medium;

3-7 (c) the maximum concentrations of each contaminant detected on-site in the area on-site where the contaminant was discharged to the environment, and/or where the worst effects of the discharge are believed to exist;

3-1 (d) whether the contaminant has promulgated state standard, the promulgated standard and the medium (i.e., ground water, surface water, air or soil) the standard applies to;

3-7 (ii) a description and list of potential human and/or environmental exposure pathways pertinent to the **Present** Use of the property;

3-7 (iii) a description and list of potential human and/or environmental exposure pathways pertinent to the **Future** Use of the property;

3-7 (iv) a list, and map defining all source areas, areas of contamination or contaminant discharge areas;

3-7 (v) a discussion of contaminant mobilities, including estimates of contaminants to be transported by wind, volatilization, or dissolution in water. For those contaminants that are determined to be mobile and have the potential to migrate and contaminate the underlying ground water resources, the applicant should also evaluate the leachability/mobility of the contaminants. This evaluation should consider, but not be limited to, the following: leachability/mobility of the contamination; health-based ground water standards for the contamination; geological characteristics of the vadose zone that should enhance or restrict contaminant migration to ground water, including but not limited to grain size, fractures and carbon content and depth to ground water. This evaluation and any supporting documentation should be included in the plant submitted to the Department.

3-12 3) The applicant should then provide, using the information contained in the application, a risk assessment in accordance with standard EPA policy, or calculation of appropriate cleanup levels, using CDHPE hazardous Materials and Waste Management Division's "**Interim Final Policy and Guidance On Risk Assessment For**

Corrective Action At RCRA Facilities" (November 16, 1993). The Department will evaluate this analysis based on an acceptable excess cancer risk of 1 x 10^{-6} or hazard index < 1.

VOLUNTARY CLEANUP PROPOSAL

The voluntary cleanup plan must address known or potential releases of contaminants considering the human health and environmental risks of those contaminants in both the present and future land use scenarios. The plan must demonstrate that wither all applicable state standards will be met, or for contaminants where no standard exists, that the risk level has been reduced to an acceptable level (excess cancer risk of 10^{-6}, or hazard index < 1).

The remediation alternative selected should be described in sufficient detail to allow the Department to evaluate whether or not the applicant will be capable of remediating all contamination identified at the subject property within the specified 24 month time limit set down in 25-16-306(4)(a). This plan should, at a minimum, include the following information:

4-1 1) A detailed description of the remediation alternative, or alternatives selected, which will be used to remove, or stabilize contamination released into the environment, or threatened to be released into the environment.

follows
4-2 2) A map identifying areas to be remediated, the area where the remediation system will be located, if it differs from the contaminated areas, locations of confirmation samples, the locations of monitoring wells, areas where contaminated media will temporarily be stored/staged, and areas where contamination will not be remediated.

follows
4-2 3) Remediation system design diagrams showing how the system will be constructed in the field.

4-7 4) A remediation system operation and maintenance plan that describes, at a minimum, how the system will be operated to ensure that it functions as designed without interruptions and a sampling program that will be used to monitor its effectiveness in achieving the desired goal.

4-7 5) The plan should describe how the waste, or contaminated media will be managed prior to treatment, and/or disposal.

4-8 6) The plan should discuss whether or not a hazardous waste will be generated by its implementation (e.g., through the excavation of contamination, which may have been discharged prior to 1980, but which would become a hazardous waste upon being dug up or managed), and the volume of this material. The plan should also describe how such hazardous waste will managed in accordance with current state and federal hazardous waste regulations.

4-8 Not Applicable 7) If applicable, the plan should describe the sampling program that will be used to verify that treatment of the contaminated media has resulted in a non-hazardous waste.

Not Applicable 8) The plan should described the sampling program that will be used to verify the no contamination above the health-based cleanup standard has been allowed to remain in the environment, or at a location that could potentially threaten human health and the environment.

Not Applicable 9) The plan should describe all sampling collection methods to be utilized along with the field and/or laboratory methods that will be used to analyze the samples.

4-9	10) The plan should include a schedule of implementation.	
4-9	11) The plan should identify all permits (Federal, state and/or local including, if necessary, EPA Form 8700-12-Notification of Hazardous Waste Activity, required on the generation of hazardous waste) that will be needed before the plan can be implemented.	
4-8	12) The plan should discuss the potential risks associated with the proposed cleanup alternatives, and the economic and technical feasibility of these alternatives.	
Not Applicable	13) The plan should describe the post-VCUP monitoring plan to be implemented in order to verify attainment of appropriate standards or risk levels as identified as cleanup targets.	
Section 3.0	14) If not included in the risk assessment portion of the application, the plan should describe:	
____		(a) a final list of all site contaminants, along with the remaining concentrations;
____		(b) a final list defining which media (i.e., soil, surface water and ground water) are contaminated, and the estimated vertical and areal extent of contamination to each medium;
____		c) a final list, and map defining all source areas, areas of contamination or contaminant discharge areas; and
____		(d) a description of the mechanisms for insuring that use of the land is consistent with the plan.

Voluntary Cleanup and Redevelopment Act Application for Grand View Smelter Site Rico, Colorado

1.0 GENERAL INFORMATION

1.1 Applicants

The property owners identified herein in conjunction with the Atlantic Richfield Company (collectively referred to as "Applicants") are submitting this application to the Colorado Department of Public Health and Environment (Department) in accordance with the requirements outlined in the Voluntary Cleanup and Redevelopment Act (HB94-1299) and the July 11, 1994 Draft Application Form.

The Applicants fully support the voluntary cleanup program as an effective mechanism to provide for the protection of human health and the environment and to foster both the redevelopment and reuse of land once occupied by the historic Grand View Smelter ("Site") in Rico, Colorado (Figures 1-1 and 1-2). The Applicants are as follows:

1. Atlantic Richfield Company, prior owner of certain property
2. Rico Properties, L.L.C., current property owner

1.2 General Site Information

This section provides general site information, as specified in the application form.

1. <u>Location and Size of Site</u>

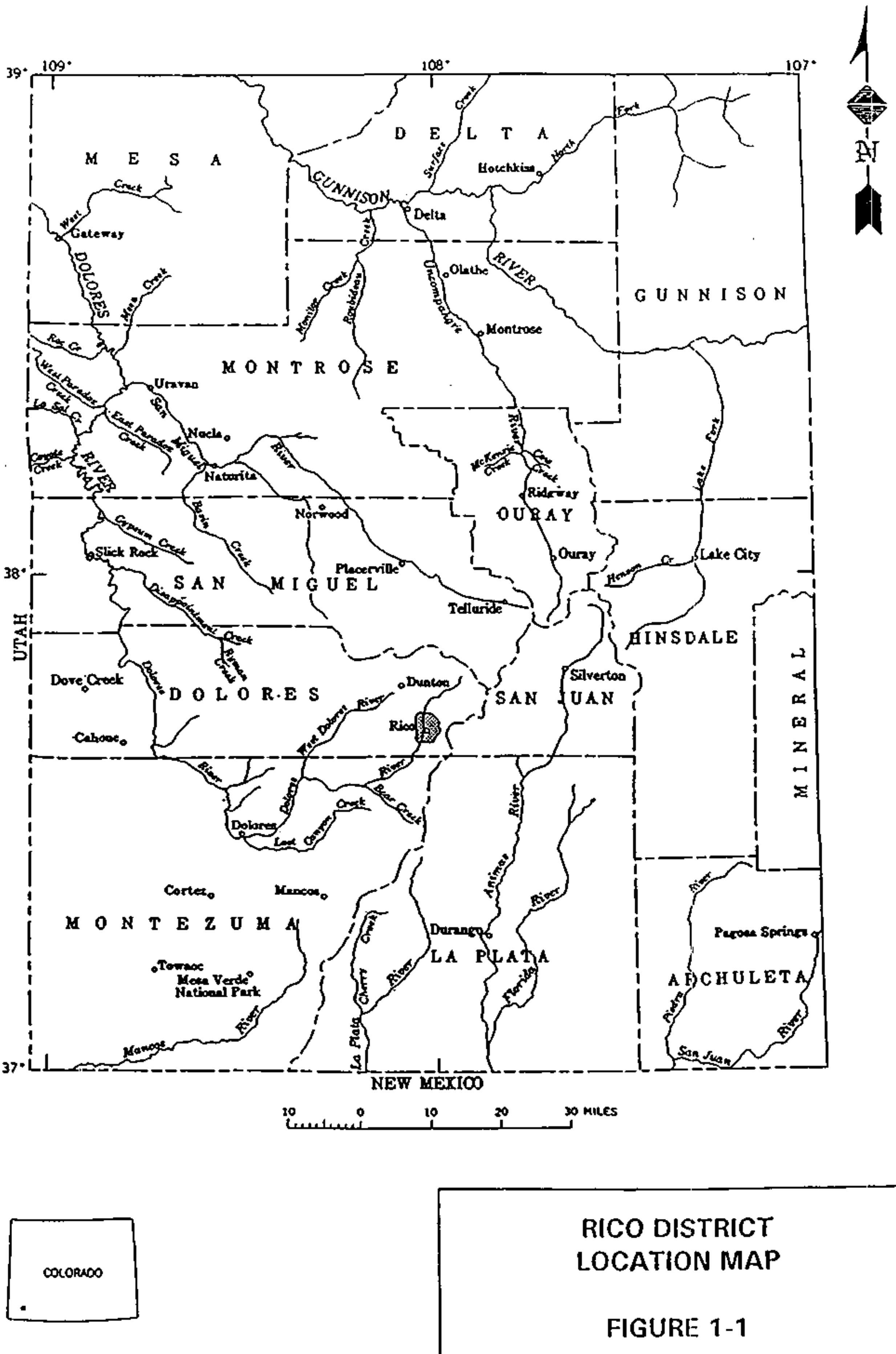
   a. General Site Location and Size.

      The Site is located on the east side of Highway 145 at the north end of the Town of Rico (Figure 1-2). The site area is approximately 1.7 acres.

   b. Land Description.

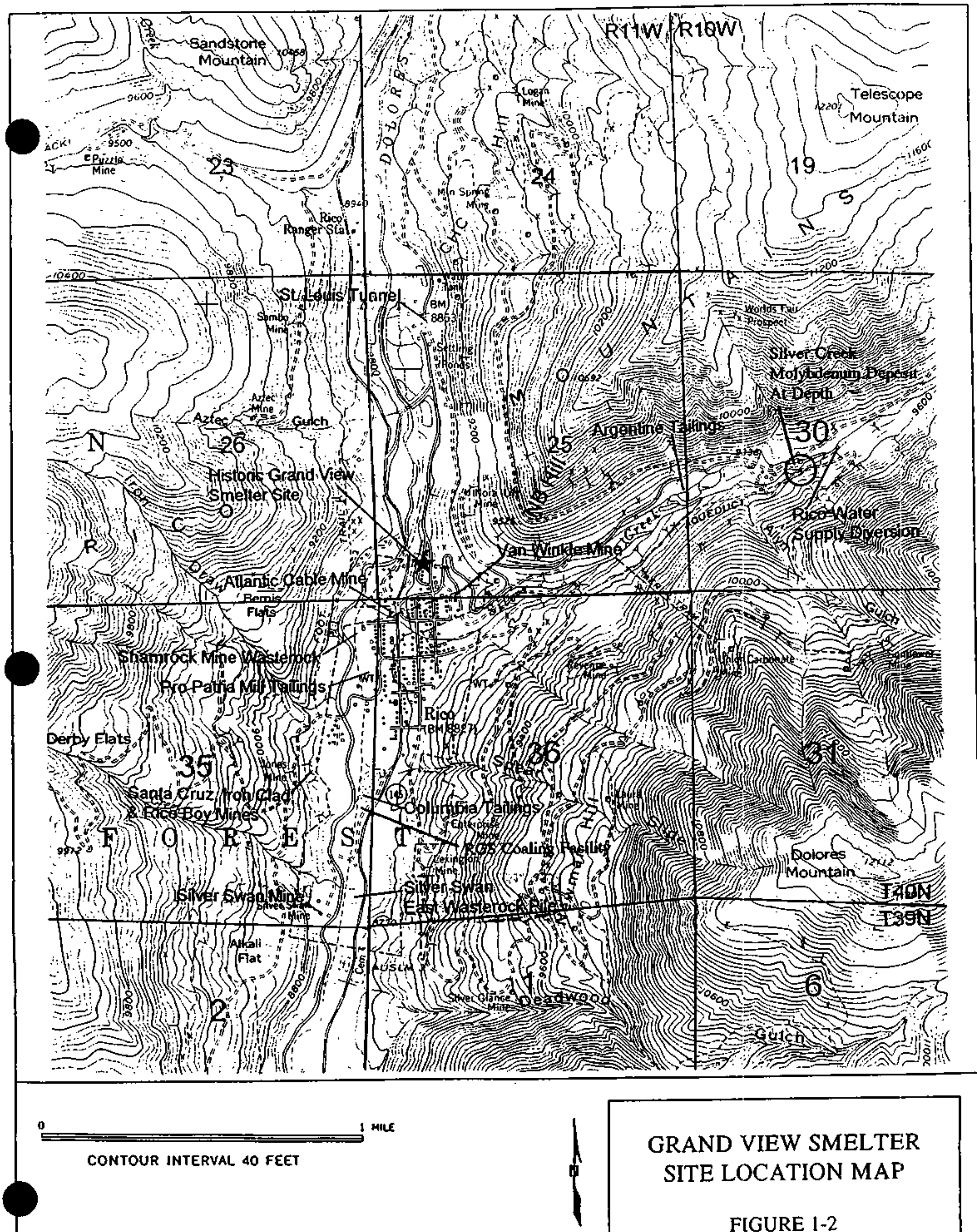
      The Site is located in the middle of the SW1/4 of the SW1/4 of Section 25, T40N, R11W, NMPM, Dolores County (Figure 1-2):

      The Site comprises various portions of the following patented mine claims (Figures 1-3 and 1-4):



RICO DISTRICT
LOCATION MAP

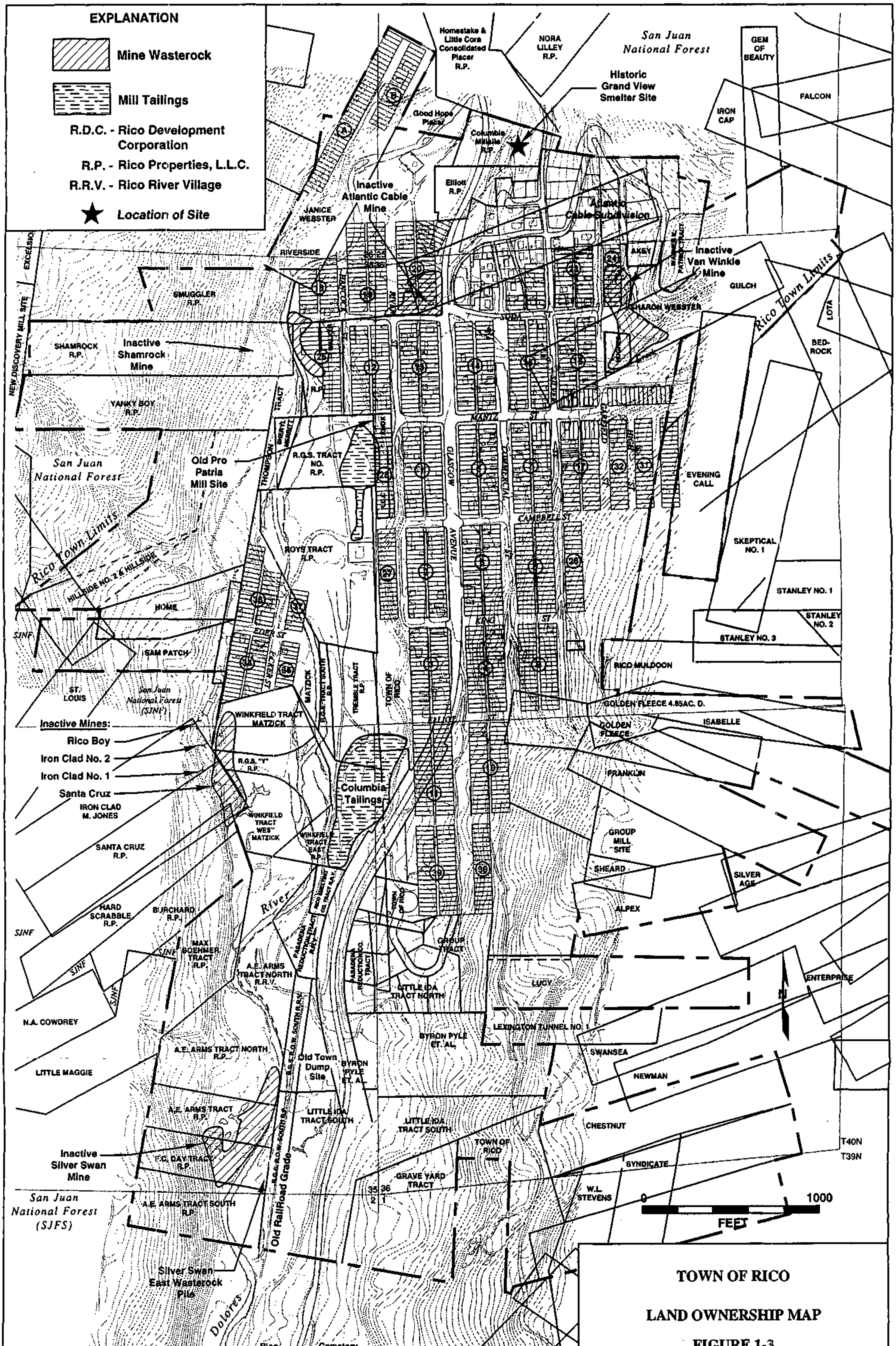
FIGURE 1-1



GRAND VIEW SMELTER
SITE LOCATION MAP

FIGURE 1-2

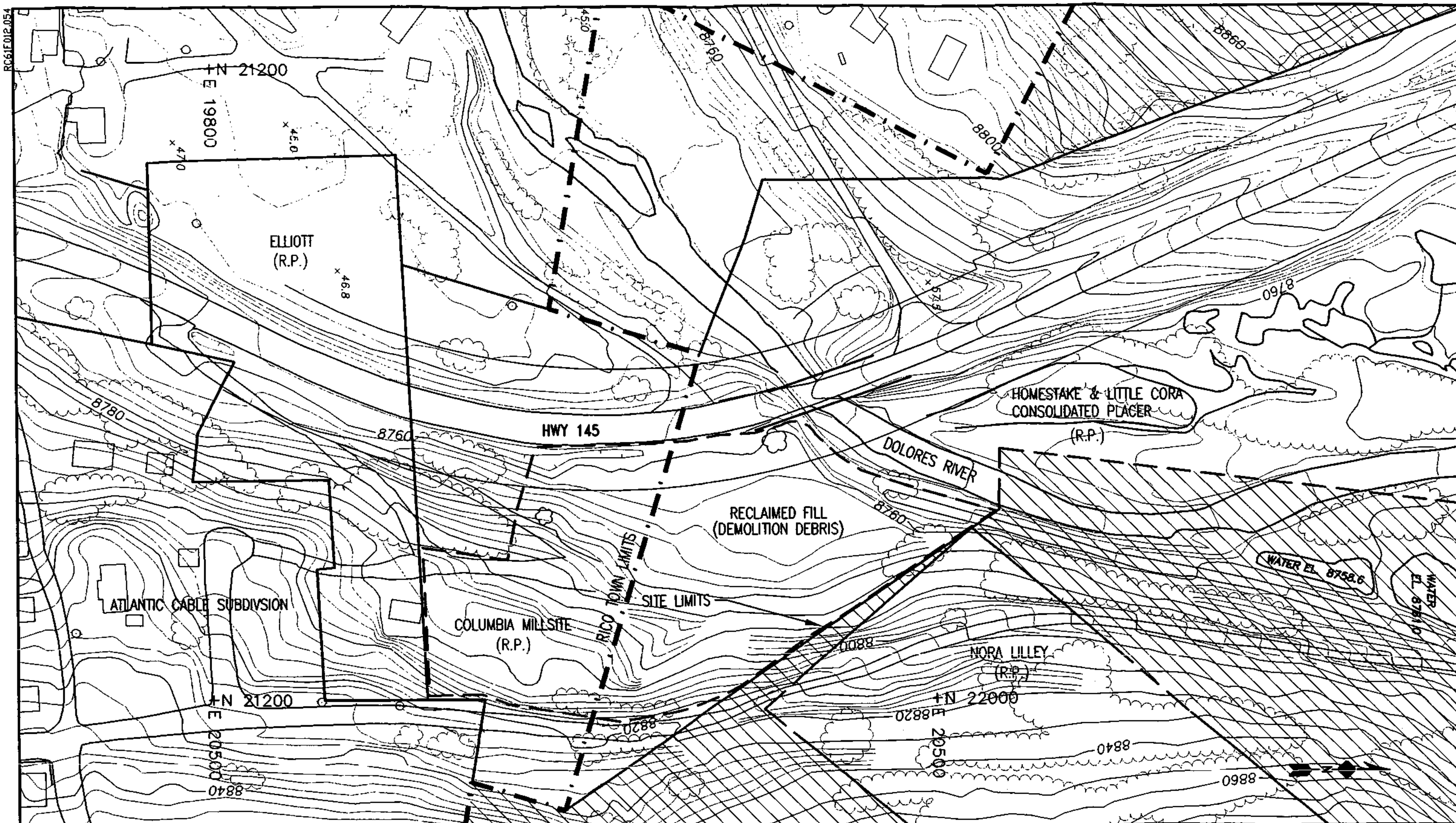
Section lines added.
Base Map: USGS Rico Quadrangle, Colorado, 7.5 Minute Series.



TOWN OF RICO

LAND OWNERSHIP MAP

FIGURE 1-3



LEGEND

SAN JUAN NATIONAL FOREST

R.P. RICO PROPERTIES, L.L.C.

SCALE IN FEET

0 100 200

CONTOUR INTERVAL 2 FEET

GRAND VIEW SMELTER SITE
LAND OWNERSHIP MAP

FIGURE 1-4

RC61E773

4-10-96

RC61E012.054

Color Map(s)

The following pages contain color that does not appear in the scanned images.

To view the actual images, please contact the Superfund Records Center at (303) 312-6473.

RICO SITE
CURRENT LAND USE

FIGURE 1-5

Claim Name	Patent No.	Mineral Survey No.
Columbia Millsite	10202	365B
Homestake & Little Cora Consolidated Placer	14903	410

2. Property Owner and Contact Person

Homestake & Little Cora Consolidated Placer and Columbia Millsite
Book 266, Pages 453 and 456

Rico Properties, L.L.C.
P.O. Box 220
17 Glasgow Avenue
Rico, CO 81332
Contact: Stan Foster, Manager, (970) 967-5441

3. Type and Source of Contamination

Heavy metals derived from historic smelter operations (predominantly cadmium, lead, manganese and zinc).

4. Site Coordinates

N21600, E20350 at center of Site based on Town of Rico survey coordinate system where N20000, E20000 is the point of intersection of Glasgow Avenue (Highway 145) and Mantz Street. Global positioning system coordinates are not available.

5. Statement of Request for Approval

The Applicants request approval of the Voluntary Cleanup Plan (VCUP).

6. Current Land Use

Vacant land. See Rico area current land use map for land use contiguous to the Site (Figure 1-5).

7. Proposed Land Use

Commercial/Residential

1.3 Program Inclusion Questionnaire

This section answers the questions listed in the application form as required to determine that the applicants meet the criteria for eligibility under the Act. An answer "yes" to question 1 and "no" to questions 2-6 indicate a determination that the application is eligible for the Voluntary Cleanup Program.

1. *"Is the applicant the owner of the property for the submitted VCUP or NAD? IF yes, verify ownership."*

   Yes. The owner application, Rico Properties, L.L.C., is the current owner of the properties for the submitted VCUP. Ownership is verified according to Book and Page number of applicable conveyance instruments on record with the Dolores County Clerk. (See Section 1.2).

2. *"Is the property submitted for the VCUP or NAD listed or proposed for listing on the National Priorities List of Superfund sites established under the federal act (CERCLA)."*

   No.

3. *"Is the property submitted for which the VCUP or NAD the subject of corrective action under orders or agreements issued pursuant to the provisions of Part 3 of Article 15 of this Title or the federal "Resources Conservation and Recovery Action of 1976", as amended? If yes, please list order number."*

   No.

4. *"Is the property submitted for the VCUP or NAD subject to an order issued by or an agreement (including permits) with the Water Quality Control Division pursuant to Part 6 of Article 8 of this Title? If yes, please list order or permit number."*

   No.

5. *"Is the property submitted for the VCUP or NAD a facility which has or should have a permit or interim status pursuant to Part 3 of Article 15 of this Title (RCRA Subtitle C) for treatment, storage, or disposal of hazardous waste? Yes, please list permit number."*

   No.

6. *"Is the property submitted for the VCUP or NAD subject to the provisions of Part 5 of Article 20 of Title 8 (Underground Storage Tank - State Oil Inspector), C.R.S. or of Article 18 of this Title (RCRA Subtitle I)?"*

   No.

2.0 ENVIRONMENTAL ASSESSMENT

2.1 Introduction

Pursuant to the specific information requirements outlined in the Voluntary Cleanup and Redevelopment Act, the environmental assessment section and appended documents and a variety of data reports provide the following categories of information:

- Qualifications of professionals who prepared the environmental assessment, applicable standards/risk determination and voluntary cleanup plan sections of this application;
- Location/size, operational history and current use of the Site;
- Physical and ecological characteristics of the Site;
- Nature and extent of on-site and off-site contamination; and
- Brief explanation as to why certain specifically requested information is not applicable.

This application presents characterization (this section) and risk assessment (Section 3.0) information for the Grand View smelter site within the context of the general Rico area and ARCO's voluntary cleanup program as a whole. The information specific to the Grand View smelter site is highlighted in **bold type.**

2.2 Qualification of Environmental Professionals

"Environmental assessments must be submitted by qualified professionals, who are defined as persons having education, training, and experience in preparing environmental studies and assessments. The applicant should submit documentation, in the form of a statement of qualifications or resume, that the environmental assessment has been prepared by a qualified environmental professional."

The environmental assessment, applicable standards/risk determination and voluntary cleanup plan have been prepared by a qualified team of environmental, risk assessment, and engineering professionals selected by Atlantic Richfield Company (ARCO). ESA Consultants Inc. is the lead firm for environmental engineering and Titan Environmental Corporation is the lead firm for the characterization and risk assessment in this application. The qualifications of the key professionals from these and other consulting firms who contributed to this application are included in Appendix A.

2.3 Location and Size of the Sites

"The applicant should provide the address (if applicable) and legal description of the site, and a map of appropriate scale identifying the location and size of the property."

The required information is provided under Section 1.2 General Site Information (Pg. 1-1).

2.4 Operational History

"The applicant should describe the operational history of the property in detail, including the most current use of the property. This description should include, but not be limited to:

- *a description of all businesses/activities that occupy or occupied the site as far back as records/knowledge allows; and*
- *a brief description of all operations which may have resulted in the release of hazardous substances or petroleum products at the site, both past and present, including the dates activities occurred at the property, and dates during which the contaminants were released into the environment."*

2.4.1 Introduction

The mining-related operations in the area of Rico, Colorado started with the staking of the first mining claim in 1869. Since then a variety of mining-related activities have taken place within and nearby to the Town of Rico. The following sections outline the key historical periods of mining-related activities with a focus on identifying the age, location, and nature of specific operations within the Town of Rico. Important references for this historical information have been Ransome (1901) for the early history of operations and McKnight (1974) for the later history. Other references are noted in the text where appropriate. The locations of key sites are shown on Figure 1-2.

2.4.1.1 1869-1894: Silver Mining

After the first mining claim was staked in 1869 (the Pioneer claim located at the mouth of Silver Creek), there was sporadic surface and near-surface exploration with limited success until high-grade silver ores were discovered in 1879. These high-grade ores were found at higher elevations on NB Hill (the result of oxidation in the upper parts of sulfide-rich veins above 9,600 feet) and on Newman Hill (silver sulfide-bearing veins and replacements, some with average grades greater than 200 opt Ag), both nearby but located outside the Town of Rico. These discoveries led to a mining boom in the area and over 8 million ounces, or about 56% of the total silver production of the district took place during this period. At the same time, only 9,235 tons or 11% of the district's total lead production took place.

Although most mining took place outside the Town of Rico during this period (the initial Atlantic Cable shaft was sunk at this time but it was primarily exploratory in nature), much of the high-grade silver ores were processed at lower elevations near the Dolores River. **Processing included milling and smelting operations such as at the Grand View smelter (constructed in 1880 and sporadically operated at a small scale through this period)**, another smelter at the south end of town constructed in 1882, and probably other small scale operations. **Of these, only the Grand View smelter has continued as a identifiable site within town (see below). Figure 2-1 shows how the Town of Rico, including the Grand View smelter, appeared at this time.**

Another important development during this period of Rico's history was the completion of the Rio Grande Southern Railroad into town in 1890. This narrow gauge railroad came up the Dolores River valley and had significant facilities within town, primarily along the river corridor (Figure 2-1). These facilities included a station house, fueling areas, a turnaround spur, a water tower (still standing), and side spurs up Silver Creek and to Newman Hill (Enterprise Mine). With the exception of the one, standing water tower, the railroad's presence is primarily evidenced today by the old railroad grade, which is still used as a dirt road and trail along the river, and widespread scattering of debris, such as cinders and coal, at various places along the river corridor. This railroad hauled much of the sulfide ore concentrates produced later in the mining life of Rico (see below).

2.4.1.2 1894-1924: Intermittent Activities

The crash in silver prices in 1893 approximately coincided with depletion of the silver-rich ores of the Rico area. Production was recorded each year but only averaged 335 tons of lead and less than 100,000 ounces silver per year through the period. The all time peak in copper production, spurred on by WW I, was reached in 1915 when 516 tons were produced. The CHC Hill area was a principal producer during this time and most ore produced in the district was shipped to the Salt Lake area for processing. The lack of effective milling technology for the complex sulfide ores was a major problem during this period particularly because the zinc sulfide mineral (sphalerite) could not be separated and a penalty was charged at the Salt Lake area

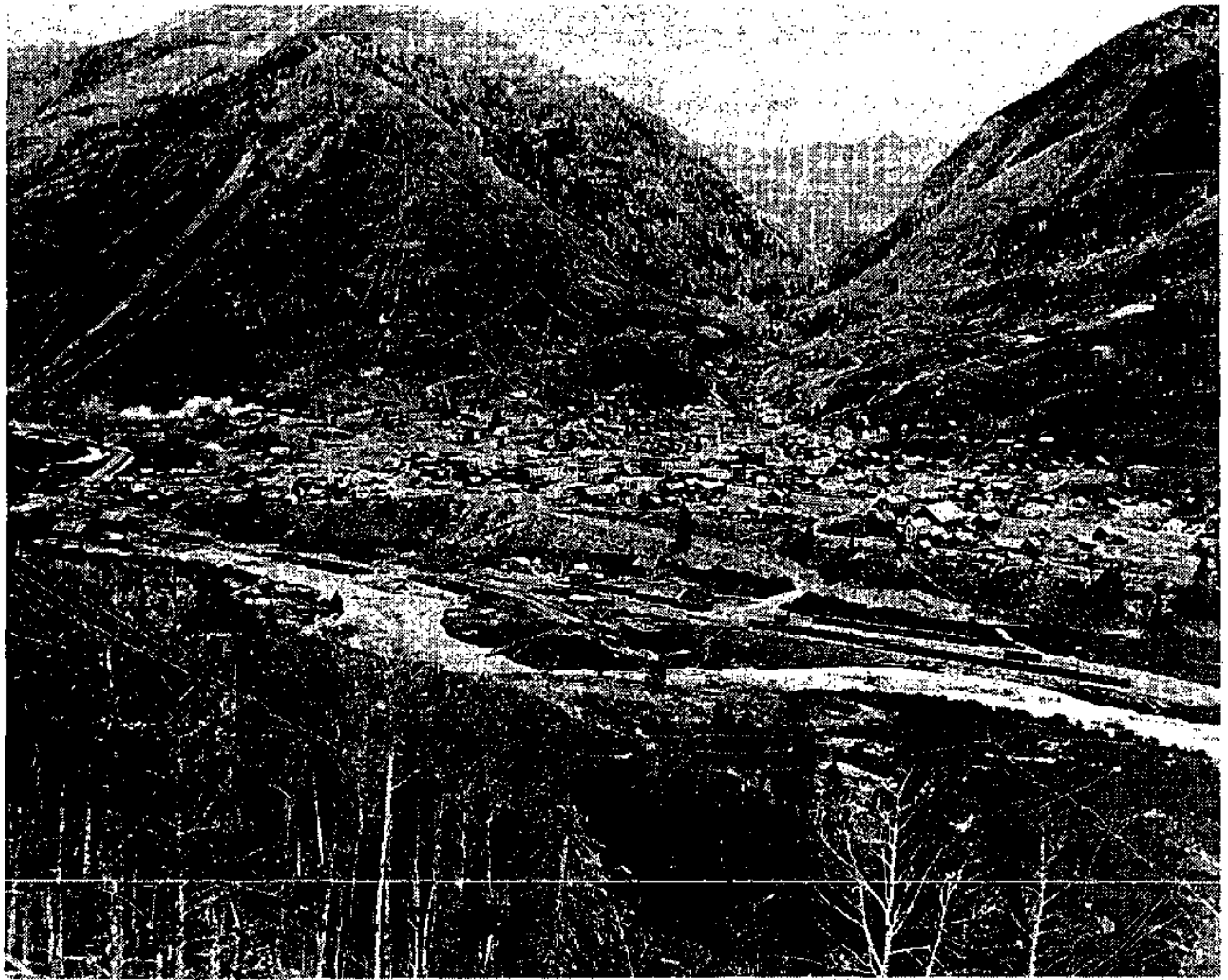


FIGURE 2-1. Photograph of Rico Sometime During the 1890's.
Smoke from the Grand View Smelter is at left-center.

smelters where the ore was processed. This problem led to the initial development of the Pro Patria mill in 1902 and a small mill using magnetic separation technology at the Atlantic Cable mine. An aerial tram was used to bring ore down to the Pro Patria mill from the Newman Hill area. The Pro Patria and Atlantic Cable sites are within the Town of Rico. Details of the Pro Patria mill history have been included in another VCUP application (Columbia tailings, Pro Patria tailings, and Silver Swan East waste rock pile application approved March 4, 1996). The Atlantic Cable mine site (Figure 2-2) is expected to become the location of community or commercial facilities (Appendix B) and is not the subject of formal VCUP activities. In general, local processing was minimal during this period as the technology needed to handle the ores satisfactorily was not available.

2.4.1.3 1924-1929: Revival Through Technology

The flotation technology for processing of complex sulfide ores had been perfected by this period and its first application in the Rico district occurred at the Pro Patria mill. The Pro Patria became a 250 ton-per-day flotation mill in 1926 and between October 1926 and July 1928 (when it was permanently closed); this mill processed most of the ore produced in the district. At other times during this period, ore production was shipped to the Salt Lake area for processing. All major mining areas were active at this time including CHC Hill, NB Hill, Silver Creek, Newman Hill, and the Shamrock and Atlantic Cable mines within the Town of Rico. Tailings from the Pro Patria mill are thought to mostly be impounded at the Columbia tailings site (see VCUP application approved March 4, 1996). Although this was a relatively short period, activity was high and the peak base metal production for the district was reached in 1927 when 5,308 tons of zinc, 4,994 tons of lead, and 65 tons of copper were produced. This promising period came to an end with the Great Depression of 1929.

2.4.1.4 1929-1939: Depression Doldrums

The district was very stagnant through this period although a large part of the St. Louis tunnel was driven under CHC Hill in the 1930 to 1932 interval. Total lead production was only 1,245 tons and no ore was processed in the area. The period is primarily noteworthy because the Rico Argentine Company, with roots dating back to 1912 in the district, effectively consolidated ownership throughout the area during this time. There were no significant mining operations in the townsite.

FIGURE 2-2. Photograph of Atlantic Cable Headframe.

2.4.1.5 1939-1971: Base Metal Mining

The potential that was evidenced in the five years before the Great Depression, was realized during this period. Rico Argentine built a 135 ton per day flotation mill up Silver Creek in 1939 and production from most mines of the area was processed here in subsequent years. Tailings from this mill, estimated to be 557,000 tons, are described in the Argentine tailings VCUP application approved on March 20, 1996.

A long crosscut from the St. Louis tunnel to the Argentine shaft on Silver Creek was completed in 1955. This crosscut and resulting drainage through the St. Louis tunnel, which continues today, lowered the water level in the Silver Creek workings some 450 feet and enabled production to continue from this area. Overall, production from several mines fed the Argentine mill on Silver Creek and 56% (over 47,000 tons) of the lead and 72% (over 59,000 tons) of the zinc production from the district took place during this period.

The Van Winkle shaft, sunk in 1942, provided significant ore to the Argentine mill for several years. This is the only production that took place within the Town of Rico during this period. The Van Winkle shaft headframe (Figure 2-3) is being preserved for historical purposes by the present owner (Appendix B).

Another significant mining-related activity near Rico during this period was the construction and operation of a sulfuric acid plant near the portal of the St. Louis tunnel. This plant, constructed in 1955 and operated for nine years, produced sulfuric acid for uranium processing elsewhere on the Colorado Plateau. The sulfuric acid was produced by roasting pyrite. This pyrite came from some 80,000 tons of Argentine mill tailings and almost 300,000 tons of pyrite ore produced from mines in the CHC Hill area. This plant produced over 300,000 tons of commercial sulfuric acid during its life. It was demolished and the plant area reclaimed in the 1980's.

This period, the time of most lead and zinc production in the district, came to a close in 1971 when the Rico Argentine mines and mill were shutdown. Some efforts to develop commercial mining enterprises did take place later (see below) but the time of significant mining activity in the area ended with shutdown of these facilities.

2.4.1.6 1971-1978: Last Mining

The Rico Argentine Company became controlled by Crystal Oil Company in 1974. The principal activity of this combined entity was the development of a leaching operation in the

FIGURE 2-3. Photograph of Van Winkle Headframe.

vicinity of the old acid plant. The leach operations processed tailings and waste rock in an effort to recover silver. Almost 200,000 tons of waste materials were treated but these operations were suspended in 1977 and never resumed.

One other significant mining-related activity took place on the west side of Rico during this period. Mining by Silver Bell Industries produced some 75,000 tons of sulfide ore from the Santa Cruz mine area from 1970 to 1975. This ore was shipped to a mill in Ophir, Colorado and not processed in the Rico area. More details of the history of this operation are provided in a separate VCUP application for the Santa Cruz mine site (submitted for CDPHE review on March 11, 1996).

2.4.1.7 *1978-1988:* Exploration

Anaconda Copper Company purchased the Rico area holdings of Crystal Oil Company and obtained other mineral rights in the area between 1978 and 1981. These holdings were obtained as part of an exploration program for a buried porphyry molybdenum deposit. The exploration program included diamond drilling from the surface and from some rehabilitated underground workings. A deep stockwork molybdenum deposit was discovered a few thousand feet below Silver Creek near the Blackhawk fault (Barrett and others, 1985; Figure 1-2). Because of it's depth, this deposit was uneconomic and Anaconda ceased exploration activities by 1983. Anaconda sold all of its Rico area holdings to Rico Development Corporation in 1988.

In conjunction with exploration activities, Anaconda completed several environmental and safety mitigation projects in the Rico area. These included demolition and reclamation of the sulfuric acid plant, construction of a water treatment plant for St. Louis tunnel discharge, hazard mitigation at many old portals, shafts, and other facilities, stabilization of the Argentine tailings ponds including partial cover and flood protection, and removal of hazardous materials from the acid plant and Argentine mill site.

2.4.1.8 *1988-Present:* Redevelopment

Mining-related activity has been minimal since 1988. In its place, the town is now experiencing a time of revitalization that accompanies real estate development as a Colorado mountain village near a major ski resort (Telluride). New roads, expansion of the community water system, active zoning, and planning for a longer term life as a residential and recreational center is underway. The community has almost 200 residents at present but with new development could grow to as many as 2,000.

2.4.1.9 Summary

Throughout Rico's history, mining and related activities have primarily been located nearby but outside the Town of Rico. The principal mining-related operations within the Town of Rico have derived from (1) **early processing of small volumes of silver-rich ores at the Grand View** and possibly one other smelter, (2) early surface and near surface exploration at the Shamrock and Atlantic Cable mines where sulfide mineralization was exposed in outcrop (Ransome, 1901), (3) operation of the Pro Patria mill and related facilities such as trams for a short period in the 1920's, and (4) production from the Van Winkle mine, primarily in the 1940's. Between 1894 and 1938 the Rio Grande Southern Railroad shipped sulfide ore for processing elsewhere, primarily in Utah. The railroad's facilities were mostly located along the river corridor.

All of these locations, with the exception of the Grand View smelter site, are the focus of active remedial or other actions to insure their compatibility with longer-term community plans and land use (see Appendix B and the Columbia tailings VCUP application). **With respect to the Grand View smelter, the following historical information is relevant. The Grand View smelter processed oxidized, silver-rich ores that contained low lead and zinc contents compared to non-oxidized sulfide ores of the district. These ores, produced from mines on NB Hill above elevations of 9,600 feet, were processed in a small blast furnace to separate silver-rich bullion from waste material or slag. Remnants of this slag are still present locally at the surface (see below) but most of the slag, along with the remains of the old facilities, were buried on site in 1993 by Rico Development Corporation.**

Reference has been made in the literature to another smelter (Pasadena) located at the south end of town. This smelter, apparently constructed in 1882 and operational for a short time in the 1880's, probably processed silver-rich ores from the Newman Hill area. Some possible remnants of this smelter facility may still be present but in general, surface evidence for it's location and nature has not been preserved. Some additional information concerning this facility site is included below.

2.4.2 Current Land Use

Applicant shall describe the *"current land uses, zoning, and zoning restrictions of all areas contiguous to the site"*.

Rico is a zoned community with a developing land use plan to guide it's future development. It now contains residential, commercial, light industrial, and recreational or open space areas; historical preservation, recreation, and tourist-related developments are expected to be important in its future. Community planning is actively underway (Community Planning Associates, 1995) but the basic outlines for longer-term land use can be generally defined (Figure 2-4). **These developing plans place the Grand View smelter site within a commercial/ residential zone,** the Atlantic Cable mine headframe area is to become open space committed to historical preservation and other community/commercial use (Appendix B), the Van Winkle shaft area is committed to open space and historical preservation (Appendix B), and various mining- or railroad-related sites along the Dolores River, such as the Pro Patria and Columbia tailings sites, become committed to open space in a river corridor set aside for recreational use.

2.4.3 Other Requested Operations Information

- A list of all *"site specific notifications made as a result of any management activities of hazardous substances conducted at the site".*

  No such activities have been conducted by the Applicants at the Site.

- A list of *"notifications to county emergency response personnel for the storage of reportable quantities of hazardous substances".*

  No such notifications have been made by the Applicants. No reportable quantities of hazardous substances are stored at the Site.

- A list of *"notifications made to State and/or Federal agencies as a reporting spills and/or accidental releases".*

  No such notifications have been made by the Applicants.

- A list of all *"known hazardous substances used at the site, with volume estimates".*

  The Applicants are not aware of any known hazardous substances used at the Site.

- A list of all *"wastes generated by current activities conducted at the site, and manifests for shipment of hazardous wastes off-site".*

  There are no current activities generating any wastes at the Site.

- A list of all *"permits obtained from State or Federal agencies required as a result of the activities conducted at the site".*

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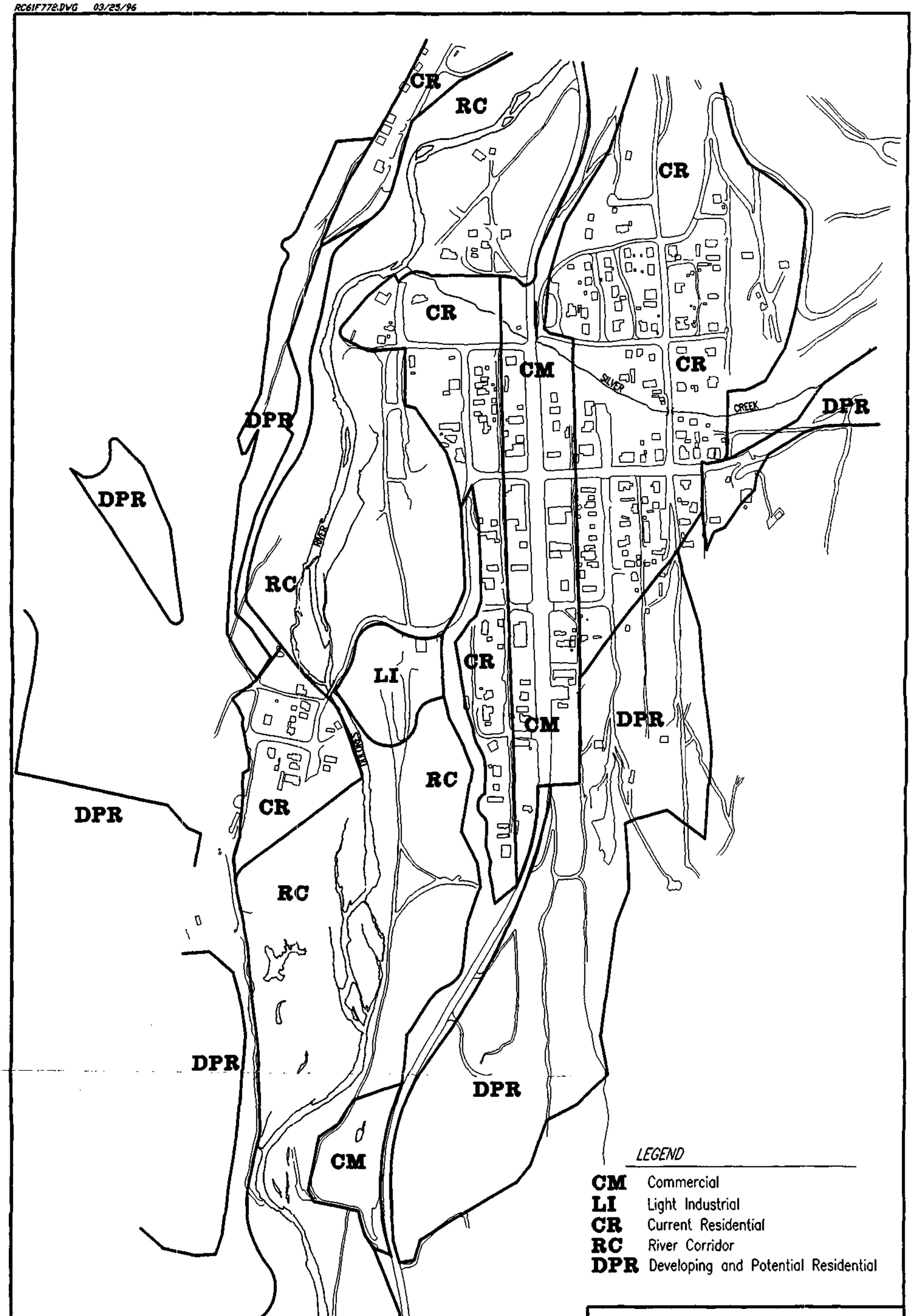


MAP SHOWING GENERALIZED CURRENT AND FUTURE LAND USE

FIGURE 2-4

CHARLES MILLER ENGEL COLLECTION – COURTESY RACHEL A. HARDWICK

SEVERAL HOUSES were destroyed during the October flood of Silver Creek in 1911. Remains of a bridge and buildings litter the creek banks after the high water had taken its grim toll. Some persons were left homeless, losing every possession they had. This picture was taken near the main street through town—Glasgow Avenue.

FIGURE 2-5. Photograph of Silver Creek After Flood of October 1911.

Due to the historical inactivity at the Site, no State or Federal permits have been required.

2.5 Physical and Ecological Characteristics of the Sites

"The applicant shall describe the physical characteristics of the site, including a map to scale (or separate maps)..."

2.5.1 Climate

The climate at Rico is characterized as semi-arid with long, cold snowy winters and short, moderately warm and wet summers. Monthly and annual climatic data has been compiled by the Colorado Climate Center at Colorado State University for Rico station 57017 from 1893 through 1993. The annual mean temperature is 38.7°F. The warmest months are June, July and August with monthly mean temperatures of about 52, 57 and 56°F, respectively. The highest monthly mean maximum and minimum temperatures also occur during these same months. The coldest months are December, January and February with respective monthly mean minimum temperatures of 6.9, 5, and 7.2°F. The growing season is relatively short because the annual frost-free period for soils ranges between 40 and 75 days (NRCS, 1995).

Mean annual precipitation is about 27 inches. Most of it occurs as snowfall in the fall, winter and spring which averages 173 inches per year. Average total monthly precipitation ranges between about 1.4 and 3 inches. Eight months average between 2 and 3 inches of precipitation and four months average between 1.4 and 2 inches. The driest month is June. The wettest months are July and August with rainfall averaging almost 3 inches each month. The driest fall month is November averaging about 1.9 inches.

2.5.2 Topography

Rico is located in the high relief southwest part of the San Juan Mountains where very steep to steep mountain sideslopes, and steep to moderate sloping tributary stream valleys, abruptly descend upon the gently to moderately sloping and relatively narrow Dolores River valley (Figures 1-2 and 2-4). Many of the steep draws and gulches formed on the hillsides on both sides of the Dolores River and its Silver Creek tributary are snow avalanche chutes. Elevations in the Rico area generally range from over 12,000 feet at the crest of surrounding mountain peaks, such as Telescope Mountain (12,201) and Dolores Mountain (12,112) to 8,700± feet in the Dolores River valley at Rico.

The intersection of Glasgow Avenue (Highway 145) and Mantz Street in the Town of Rico is at about 8,800 feet elevation. Most of present day Rico is built on moderate to low slopes developed where tributaries deposit alluvial fans on the Dolores River flood plain. These low slopes continue to be preferred for development but because of their limited area, new development (particularly residential), is expanding onto steeper slopes surrounding the town (Figures 1-2 and 2-4).

The Grand View smelter site is on a colluvium-mantled surface adjacent to Highway 145 and the Dolores River flood plain. Slopes here are moderate and two dirt roads traverse the area (Figure 1-4).

2.5.3 Surface Water Bodies

The Dolores River below the Town of Rico has a mean annual historic flow of 132 cfs with a typical seasonal flow range of between 20 and 600 cfs. The annual high flows occur during snowmelt runoff in May and June. The annual low flow period occurs in November through March with January and February having the lowest average monthly flow of 19 and 18 cfs, respectively. The 100-year flood peak is estimated at about 2,700 cfs (D&M, 1981).

Silver Creek, the principal tributary to the Dolores River in the area, drains through the Town of Rico. The gradient of the relatively narrow cobble and boulder-lined channels is moderate where it passes through Rico. Historic instantaneous measurements of Silver Creek flow below the Argentine tailings ponds range from 0.06 cfs (26 gpm) to 23 cfs for the period 1980-1995. Most annual high flows occur during snowmelt runoff in the spring and early summer months (April-July). Infrequent floods result from high-intensity rainfall during the summer months (Figure 2-5). The 100-year flood peak flow is estimated at about 525 cfs (D&M, 1981). In Rico, the channel is locally incised and confined by flood control banks.

2.5.4 Surface Water and Ground Water Supplies

The surface waters within the Town of Rico are not used as a water supply source for the town. Silver Creek, from a diversion point located approximately 1.25 miles above the town site, is the town's source of water (Figure 1-2). Although the west Rico area is also served by the Town's water supply system, at least three residences obtain water from surface runoff in Iron Draw.

There are no known ground water monitoring or supply wells within the Town of Rico. Colorado Division of Water Resources records were searched for all registered wells in the east end of Dolores County. Most of the wells on record are located in the Dunton area within the West Dolores River Basin (Figure 1-1).

There are three registered supply wells in the Rico area. These are located upstream and north of the town on the west side of the valley (Figure 2-6). Two of the wells supply water for domestic use and are located one mile upstream of the town. The third well was used by the Colorado Department of Transportation. This well has been abandoned and plugged. There are no known unregistered water wells within the town site or along the Dolores River.

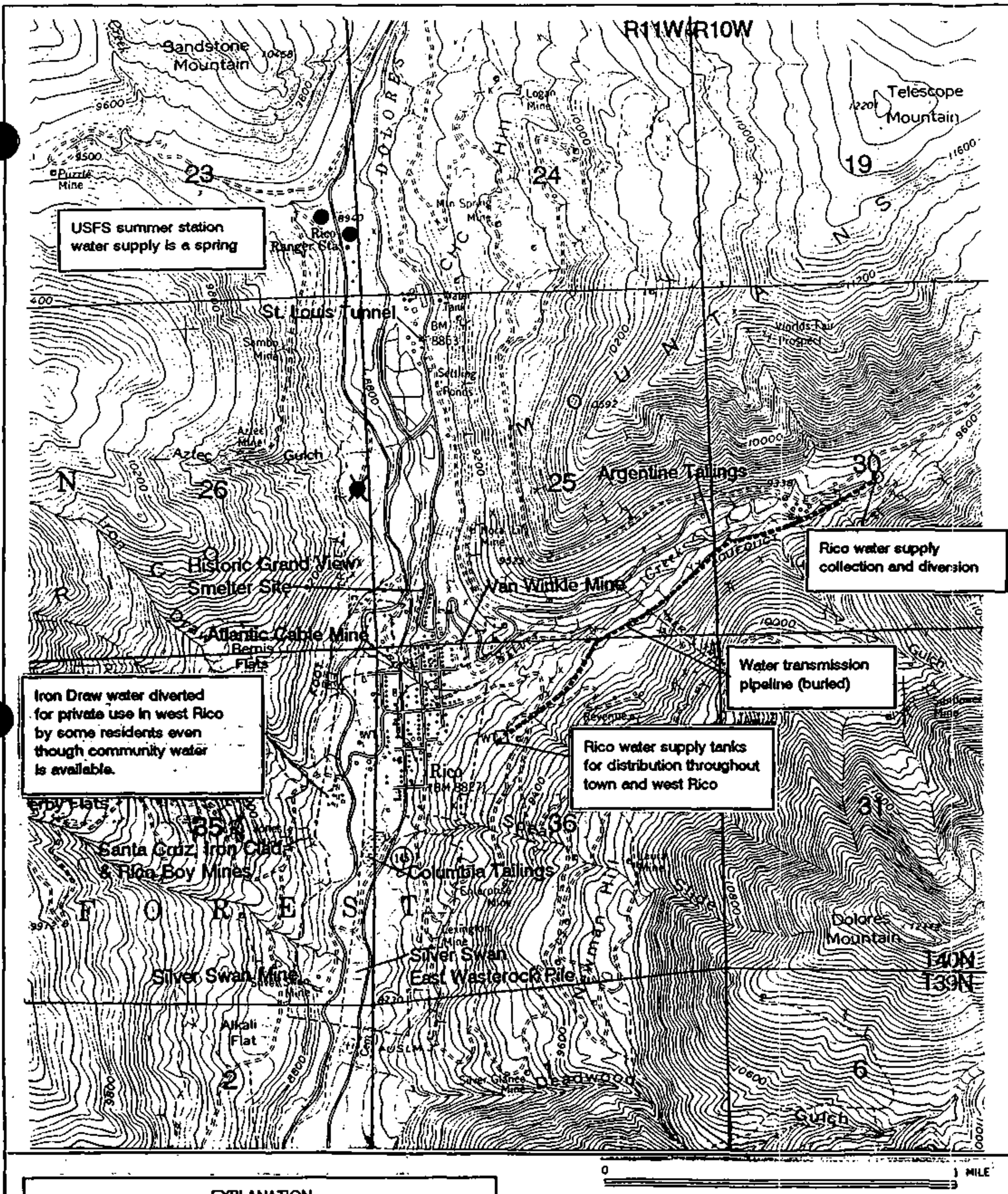
2.5.5 Vegetation Communities/Wildlife Habitats/Sensitive Species

An ecological investigation of the Rico area was conducted by Cedar Creek Associates in June 1995 to characterize major vegetation communities/wildlife habitats, identify general impacts from mining-related and other land use disturbances, and assess the potential occurrence of sensitive species. The area of investigation included the Dolores River valley between Horse Creek and the Rico Cemetery. The results of the investigation are provided in a report prepared by Cedar Creek (1995), which has been submitted under separate cover. Ecological characterization information applicable to the Town of Rico is summarized in the following discussion. Figure 2-7 is a vegetation communities/wildlife habitats/land use map of the Dolores River valley in the Rico area.

2.5.5.1 Vegetation Communities/Wildlife Habitats

The predominant vegetation communities within the Town of Rico are those developed in mostly residential areas, those in the nearby uplands, and those in the Dolores River corridor. The residential areas typically have rocky soils that have been reworked, with marginal success, in attempts to diminish the proportion of coarse gravel and colluvial debris and foster the growth of natural and planted grasses.

The uplands nearby are vegetated with a mix of aspen woodlands, mountain meadows, and to the west of the Dolores River corridor, some areas of spruce-fir woodland. The aspen community is located up to about 9,500 feet elevation and principally on westerly and southerly facing slopes. The structural diversity and condition of the aspen community is good to very good and stable. Overall, the apparent biodiversity of this community is good with use as a wildlife habitat considered very good, especially for big game species. The spruce-fir community is located primarily above 8,500 feet elevation. The structural diversity and condition of the spruce-fir woodland is excellent and stable. Overall, the apparent biodiversity of this community appears to be very good with use by wildlife, especially big game species, at expected levels.



EXPLANATION

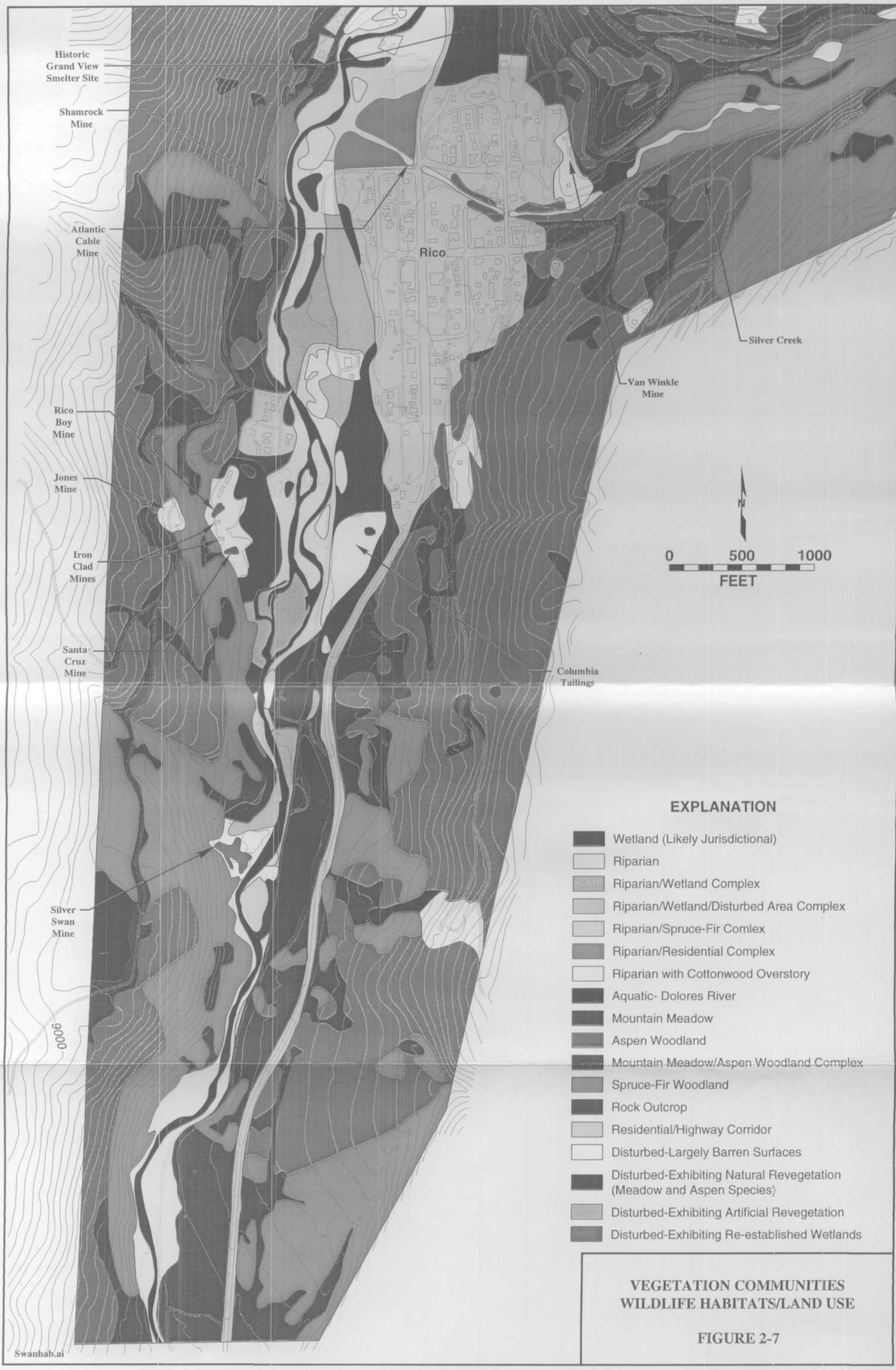
- Permitted household use only supply well - upgradient of Rico Townsite
- Abandoned and plugged Colorado Department of Transportation supply well

No registered or unregistered domestic or irrigation supply wells, or monitoring wells exist within the half-mile radius of site.

Section lines added.
Base Map: USGS Rico Quadrangle, Colorado, 7.5 Minute Series.

COMMUNITY WATER SUPPLY
AND
GROUND-WATER SUPPLY WELLS

FIGURE 2-6



VEGETATION COMMUNITIES
WILDLIFE HABITATS/LAND USE

FIGURE 2-7

The Dolores River corridor contains a complex mix of wetland and riparian vegetation communities and habitats. The natural wetland community/habitat along the Dolores River riparian corridor occurs as unique community units or interspersed with the riparian community as a "complex" (Figure 2-7). The structural diversity of the wetland community is fair to good owing to a dense herbaceous stratum interspersed with some pools and ponds and an intermittent, and often thick, shrub stratum typically dominated by willows. The wetland community's utility as wildlife habitat is superior to all other communities with the possible exception of the riparian type. Wetlands provide an excellent source of both forage and cover to a wide variety of species, from big game to furbearers to avifauna. The natural wetlands condition and trend are rated very good and stable, respectively.

The riparian community/habitat exhibits principally a shrubby physiognomic character owing to the predominance of willows and young cottonwoods and alders. The structural diversity of the riparian community is good to excellent. This is evidenced by the existence of dense herbaceous stratum bisected by stream or river interspersed with thick shrub stands typically dominated by willows, alders, and young cottonwood. The riparian community's utility as wildlife habitat is superior to all other communities with the possible exception of the wetland type. Like the wetland type, the riparian community provides water and is an excellent source of both forage and cover to a wide variety of species, from big game to furbearers to avifauna. Furthermore, the physiognomic and topographic nature of the community enhances its utility as a travel corridor for migratory big game animals such as elk and mule deer.

Several mining-related sites in the Rico area are being revegetated by planned reclamation activities (see Silver Swan mine, Santa Cruz mine, and Columbia tailings VCUP applications) or are becoming naturally revegetated. The possible location of the old smelter on the south side of town is now an area of mature mountain meadow and aspen woodland development. **A photograph of the Grand View smelter site (Figure 2-8) shows that natural grassy revegetation is sparse here.** The wasterock dump at the Van Winkle mine is largely unvegetated but patches of meadow and aspen woodland are encroaching around it's base (Figure 2-8). The coarse limestone-dominant character of this dump, together with its steep slopes and relative youthfulness, has inhibited revegetation although it is not acid generating.

2.5.5.2 Threatened/Endangered Species and Critical Habitats

There are no known or suspected occurrences of listed threatened or endangered species or critical habitats in the Dolores River valley at Rico (Cedar Creek, 1995).

Figure 2-8. Aerial Photograph of Historic Grand View Smelter Area (view east). September 1995.

2.5.6 Geology

2.5.6.1 Introduction

A bedrock and surficial geology framework for the Rico area enables the principal controls on metal distribution in surficial materials to be defined. This geologic framework relies on information available in published literature (Ransome, 1901; Pratt, McKnight, and De Hon, 1969; McKnight, 1974), historic mining data from private files, and recent studies (Walsh, 1995; PTI, 1995a; Russ, 1996) that focus on characterizing surficial materials and identifying the principal surficial geologic processes active in the area. This has enabled the various surficial materials in the area to be defined and individually described and mapped. Having well-defined categories of surficial materials, "surficial units", in turn enables a sampling program to be carried out that can accurately represent their metal-bearing character. The resulting well-defined origins, spatial relations, and character of the surficial units combine to provide an understanding of the controls on metal distribution in the Town of Rico.

As would be expected in a historic mining district discovered in the late 1800's, highly mineralized natural materials are exposed at the surface in Rico. Detailed mineralogy studies show that the metal-bearing minerals in bedrock are the same minerals that are found in surficial materials of the area. These minerals, weathered from bedrock and incorporated in surficial materials in various concentrations throughout the area, are the principal source of metals. These natural sources dominate in the Rico area as mining-related sources, natural materials themselves, are discrete and localized.

The approach used here to develop a geologic framework starts with a regional perspective and successively focuses in on the Rico area, and subareas, in greater and greater detail. This approach allows more local specific relations to be placed in context and increases our understanding of the controls on metal distribution as a whole.

2.5.6.2 Regional Setting

The mineralization at Rico is ultimately related to the evolution of the San Juan Mountains. These rugged and high mountains are located near the northern end of a very large crustal feature known as the Rio Grande Rift. The Rio Grande Rift extends southward from near Leadville, Colorado over 600 miles to the El Paso, Texas area (Figure 2-9; also see Keller and Cather, 1994). It is an elongate, narrow (less than 60 miles wide) feature marked by geologically youthful (26 Ma to the present) crustal thinning, extensional basin development, and irregular emplacement of igneous rocks along its length. These aspects contribute to one of its important

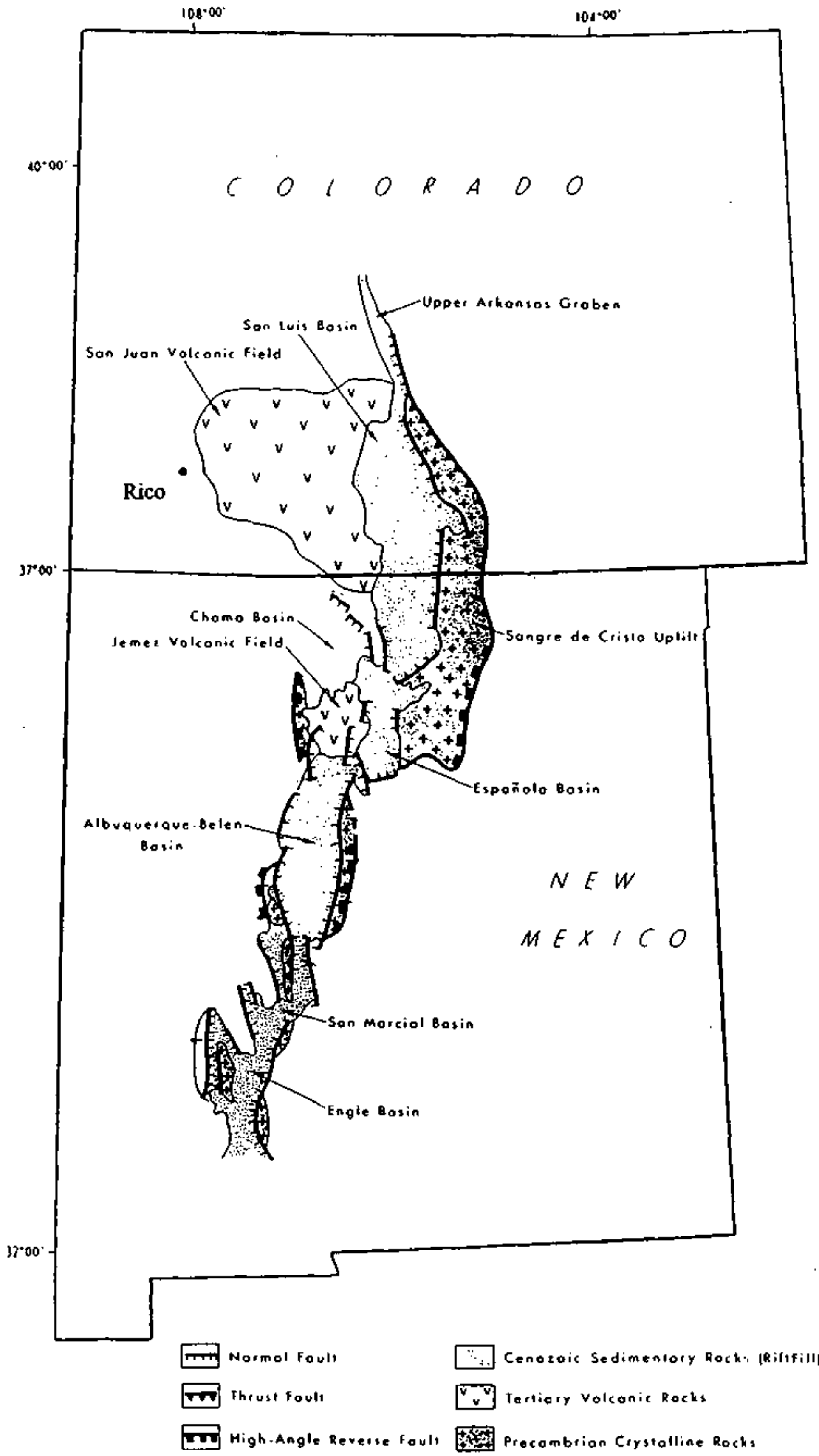


FIGURE 2-9. Rio Grande Rift Location and Features (from Keller and Cather, 1994)

characteristics; it is a crustal-scale locus of high heat flow. Some of the related igneous rocks, the large San Juan Volcanic Field (in some directions over 100 miles across, Figure 2-9), form the heart of the San Juan Mountains. These igneous rocks, some as young as 3.5 Ma (see Curtis, 1975), are exposed only 18 to 36 miles east of Rico (Tweto, 1975). The Rico district has structural, magmatic, paleothermal, and mineralization components that tie it to the San Juan Volcanic Field and ultimately the evolution of the Rio Grande Rift.

2.5.6.3 Rico District Setting

In many respects, Rico is a geologic anomaly. It is a center of young structural uplift, igneous intrusion, thermal recrystallization and related mineralization. However, to better understand Rico's younger geologic characteristics, discussed more below, it's first necessary to review the older geologic components upon which they are superimposed. These older components, Early Tertiary (about 60 Ma) and older, include stratigraphic, structural, and igneous elements. Figure 2-10 shows the exposed spatial relations of these older components.

The older stratigraphic relationships are summarized in Figure 2-11. The oldest, or basement rocks, in the area are metamorphosed mafic volcanic rocks or greenstones, that are Precambrian age (1600 to 1700 Ma) (Tweto, 1979). Deposited unconformably on these greenstones and locally preserved, are Precambrian age Umcompahgre Quartzite and sedimentary rocks of Paleozoic age which comprise most of the rocks exposed at the surface in the Rico area. These include 100 to 200 feet of limestone, primarily Leadville Limestone of Lower Mississippian (about 350 Ma) age, that is overlain unconformably by a few thousand feet of Middle to Upper Pennsylvanian (about 290 Ma) marine sedimentary rocks, including a middle Hermosa Formation limestone-rich section. The marine sedimentary rocks transition upward to several thousand feet of non-marine sandstone, shale, and conglomerate of Permian (about 260 Ma) Cutler Formation redbeds. The limestone-bearing intervals in the Paleozoic section are especially important because they preferentially host the lead-zinc-silver deposits of the Rico area; Leadville Limestone hosts the Shamrock, Atlantic Cable, and Van Winkle deposits in the townsite and the middle Hermosa Formation limestones commonly host the sulfide deposits present elsewhere.

About 65 Ma (Late Cretaceous to Early Tertiary), was a time of compressional deformation, crustal thickening, and related magmatism in the southern Rocky Mountains. In Rico, a structural dome developed that is about 10 miles across and has over a mile of vertical relief. This dome is centered in the area of basement greenstone exposure about where Highway 145 crosses the Dolores River on the north side of town. Development of this dome was accompanied by extensive faulting that relatively uplifted the basement rocks and variably offset all the major stratigraphic units in the area. Several of the faults, trending about east-west, are

Source: Pratt, Walden P., Edwin T. McKnight and René A. DeHon. 1969. Geologic Map of the Rico Quadrangle, Dolores and Montezuma Counties, Colorado. USGS Geologic Quadrangle Map GQ-797.

GEOLOGIC MAP OF A PORTION OF THE RICO QUADRANGLE

FIGURE 2-10

GEOLOGIC MAP EXPLANATION

Geologic Age	Map Symbol	Map Unit Description
Holocene	Qal	Alluvium. Coarse stream deposits (sand, gravel and boulders) confined to the Dolores River valley flood plain. The flood plain is narrowed by encroachment of torrential fan debris at the mouths of large tributary streams.
	Qf	Torrential fans. Cone-shaped deposits of coarse alluvium formed at the mouths of such tributary streams as Horse Creek, Aztec Gulch, Silver Creek, and Deadwood Gulch.
	Qtw	Talus and slope wash. Shown principally where bedrock relations are significantly obscured. Mantle of extensive soil and coarse rock debris that has accumulated on the lower slopes of mountains at Rico. The debris has washed or fallen down from higher slopes.
	Ql	Landslide deposits. Individual blocks of rock and/or talus and slope wash deposits that have broken loose and moved en masse down mountain slopes. The extensive landslide material underlying CHC Hill is several hundred feet thick and had to be traversed by most of the mines on this hill. No such landslide deposits exist in the Rico townsite area.
	Qtu	Calcareous tufa. Patches of calcium carbonate deposited from solution of water from an unidentified spring, which cap the slopes of the landslide and wash debris in the Alkali Flat area above the Silver Swan mine on the west side of the Dolores River south of Sulphur Creek.
Lower Tertiary	Tm	Augite monzonite. Medium-gray instrusive stock west of Rico composed of andesine crystals and interstitial potassic feldspar, hornblende, or augite and biotite, minor quartz, and accessory apatite, sphene, and magnetite.
	Tlh	Hornblende lamprophyre. Dark-gray fine-grained rock composed of crystals of hornblende, quartz, agate and olivine in a groundmass of plagioclase, hornblende, agate, and minor amounts of biotite, magnetite, and alternation products. Forms dike in middle member of Hermosa Formation (PPhm) east of Laura mine on Newman Hill.
	Tap	Alaskite porphyry, conspicuous rounded crystals of quartz and, locally, potassic feldspar, in pale-gray fine-grained groundmass of potassic feldspar and subordinate quartz. Forms small dikes, 10-15 feet wide, in lower member of Hermosa Formation (PPhl) in Aztec Gulch and in upper member of Hermosa Formation (PPhu) south of Silver Creek.
	Tlf	Hornblende latite porphyry. Abundant white plagioclase crystals in altered groundmass which ranges from light to dark gray, greenish gray, or brownish gray, depending on abundance of chlorite and iron oxides as alteration products. Forms sills and small laccoliths a few feet to several hundred feet thick and dikes a few feet to several tens of feet wide, throughout the Rico Mountains.
Lower Permian	Pc	**Cutler Formation**: Interbedded siltstone and arkose. Siltstone is shaly, poorly sorted, and locally micaceous and (or) arkosic; generally reddish brown; includes minor fine-grained sandstone beds and nodular limestones. Arkose is generally coarse grained, locally conglomeratic, grading into arkosic conglomerate, and commonly crossbedded; generally purplish brown or banded purplish brown and grayish pink; conglomeratic beds pinkish gray or greenish gray. Commonly bleached to gray near large intrusions or major faults. Generally crops out as rounded ledges (arkose) alternating with undercuts or slopes (siltstone). About 2,100 feet thick where measured in northeast part of quadrangle.
Middle Pennsylvanian	Ppr	**Rico Formation**: Predominantly sandstone and arkose, in part conglomeratic, and subordinate shale and shaly limestone; sandy beds greenish gray, pinkish gray, purplish gray, or reddish brown; shaly beds commonly reddish gray or maroon, some greenish gray; limestones mostly gray or green, thin, and gnarly. Overall outcrop massive because of prevalence of thick sandstones and arkoses, in contrast to Cutler Formation. Marine fossils present in some limestones and limy sandstones. Top is thick massive sandstone. Base is a 10- to 25-foot-thick unit of dark-greenish-gray limy or sandy shale that overlies uppermost bed of Hermosa Formation. About 260-325 feet thick.
		Hermosa Formation
	PPhu	Upper member: Arkose, sandstone, some shale, some conglomerate (in upper half only), and minor thin beds of limestone, some of which are fossiliferous; uppermost bed is a 1-foot-thick bed of brownish-gray shaly or sandy limestone; brownish red or purplish gray, especially in upper part, and greenish gray, especially in lower part. About 720-830 feet thick.
	PPhm	Middle member: approximately one-half arkosic sandstone, one-third limestone, one-sixth shale. Distinctive feature of member is limestone; it is medium to dark gray, massively bedded, fine grained, fossiliferous, and mostly in units 10-40 feet thick, which are separated by greenish-gray, dark-gray, or locally brownish-red sandstones and shales. About 600-650 feet thick in Sandstone Mountain and Silver Creek, thinning to about 280 feet in Newman Hill, where massive limestones constitute about two-thirds of member.
	PPhl	Lower member: greenish-gray buff-weathering micaceous sandstone, siltstone, and arkose, locally conglomeratic, black and gray shale, and minor dark-gray limestone or dolomite; sandstone and arkose massively bedded or crossbedded, siltstone and shale thin bedded and slabby. Incompletely exposed; at least 880 feet thick.
	PPl	**Quartzite of Larsen tunnel area**: Coarse-grained quartzite containing quartz grains as much as 1-inch across in finer grained quartzose matrix; gray to brown, locally reddish gray; upper part interbedded with light-gray siltstone or shale, lower part massively bedded. Crops out near Larsen tunnel (one-half mile east of Rico along Silver Creek); narrow band through Rico is projected from underground workings and drill holes. About 80 feet thick, decreasing to 0 locally on west bank of Dolores River at Rico; basal contact not exposed.
Lower Mississippian	Ml	**Leadville Limestone**: White to gray crystallinelimestone and dolomite containing contact-metamorphic silicates and, locally, minor light-gray chert. Maximum exposed thickness 20 feet. Underlain in subsurface by Ouray Limestone of Late Devonian age; total aggregate thickness of both formations 120 to 170 feet.
Precambrian	p€u	**Uncompahgre Quartzite**: Pale-gray well-indurated quartzite, commonly stained red, containing quartz grains and pebbles; bedding generally obscure; pyritized chlorite schist layers and a light-gray dolomite bed present locally. Thickness unknown, but possibly greater than 1,000 feet.
	md	**Metadiorite**: Dark-gray coarse- to fine-grained unfoliated rock containing hornblende crystals and minor plagioclase crystals, in a fine-grained matrix of feldspars, quartz, hornblende, biotite, and chlorite; occurs as lenses and pods in greenstone (g).
	g	**Greenstone**: Dark-greenish-gray fine-grained rock, generally unfoliated or poorly foliated but locally phyllitic, consisting of quartz with either actinolite, or muscovite and biotite, and with chlorite and epidote.

80

Contact, showing dip

Long dashed where approximately located; short dashed where indefinite or inferred; dotted where concealed

70 90 ?

Fault, showing dip

Long dashed where approximately located; short dashed where inferred; dotted where concealed; queried where existence is uncertain. Bar and ball on downthrown side. Vertical displacement, in feet, shown where measured or calculated. Faults in landslide area of CHC Hill projected from underground workings

Concealed inferred fault

Approximate crestline of elongated dome

?

Doubtful syncline

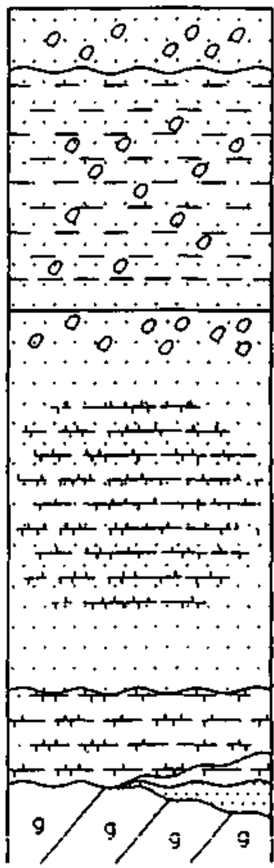
15			75
Strike and dip of beds	Strike of vertical beds	Horizontal beds	Strike and dip of foliation

FIGURE 2-10b

Source: Modified from Pratt, Walden P., Edwin T. McKnight and Rene' A. DeHon. 1969. Geologic map of the Rico Quadrangle, Dolores and Montezuma Counties, Colorado. USGS Geologic Quadrangle Map GQ-797; *and* McKnight, Edwin T. 1974. Geology and ore deposits of the Rico District, Colorado. USGS Professional Paper 723.

STRATIGRAPHIC COLUMN SHOWING GENERALIZED LITHOLOGIC AND DEPOSITIONAL RELATIONS BETWEEN THE MAJOR SEDIMENTARY FORMATIONS OF THE RICO AREA

DRAWING NUMBER 3110-A10



Pb-Zn-Ag DEPOSITS	FORMATION/LITHOLOGY	AGE	COMMENTS
	UNCONSOLIDATED DEPOSITS (0-500 FEET THICK)	HOLOCENE	ALLUVIUM, COLLUVIUM, TALUS
	CUTLER SILTSTONE, ARKOSE, CONGLOMERATE (2000+ FEET THICK)	LOWER PERMIAN	NON-MARINE RED BEDS
	RICO (SANDSTONE)		REGRESSION AND TRANSITION TO NON-MARINE
	HERMOSA CONGLOMERATE, SANDSTONE		
NEWMAN HILL SILVER CREEK NB HILL CHC HILL	LIMESTONE (>2700 FEET THICK)	MIDDLE TO UPPER PENNSYLVANIAN	CARBONATE SHELF
	SILTSTONE, SANDSTONE		
	LAWSON QUARTZITE (<100 FEET THICK)	UNCONFORMITY	MARINE TRANSGRESSION
ATLANTIC CABLE VAN WINKLE SHAMROCK	LEADVILLE LIMESTONE (100-200 FEET THICK)	LOWER MISSISSIPPIAN	KARST
	OURAY LIMESTONE	UPPER DEVONIAN	
	UNCOMPAHGRE QUARTZITE GREENSTONE BASEMENT	PRECAMBRIAN	

LITHOLOGY OF
RICO MINE
RICO, COLORADO
PREPARED FOR
ARCO
DENVER, COLORADO

TITAN Environmental

No.	DATE	ISSUE / REVISION	DWN. BY	CK'D BY	AP'D BY
1		ISSUED FOR BCUP APPLICATION/RICO COMMUNITY SOILS.	D.A.S.		

DATE: 3-8-96	FIGURE 2-11	DRAWING NUMBER 3110-A10
SCALE: AS SHOWN		

especially prominent in the north part of town and nearby where they are exposed at the surface and in underground workings of NB Hill (Figure 2-10). This deformation fractured all the bedrock units to some degree and initially established many of the permeable conduits that channeled mineralizing fluids later. This deformation was accompanied by many igneous intrusions of latite porphyry in the Rico area (Figure 2-10). These intrusions heated and recrystallized the surrounding sedimentary rocks to various degrees (McKnight, 1974) but in general the principal time of hydrothermal mineralization was later. In fact, latite porphyry itself later became highly fractured and mineralized in the Rico area (see below).

Superimposed on the stratigraphic, structural, and igneous elements outlined above was a very young structural, igneous, and related hydrothermal event that had profound impacts on the Rico area. This event, taking place only about 3 to 5 Ma ago, was the principal time of ore deposition and related alteration in the district (Naeser and others, 1980; Cunningham and others, 1987). At this time, many faults were reactivated, additional fracturing of country rocks took place, intrusions of alaskite porphyry were emplaced (mostly in the subsurface), and a large hydrothermal mineralizing system developed within and around a deep-seated alaskite intrusion. This hydrothermal system produced the Silver Creek molybdenum deposit (Figure 1-2) within and nearby to the alaskite intrusion (discovered by Anaconda Minerals Company in 1980, Barrett and others, 1985) and the base and precious metal deposits peripheral to the molybdenum deposit that have been the focus of historical mining in the district.

The results of recent geochemistry, mineralogy, geochronology, and stable isotope studies (Larson and others, 1994a; 1994b; Meuzelaar, 1995) show that extensive hydrothermal flushing and accompanying alteration affected the entire Rico dome area at this time. The alaskite intrusions at depth were a heat and magmatic hydrothermal source that mobilized a meteoric hydrothermal system around it. The combined hydrothermal system was strongly developed over a height of at least 1.5 miles and width of 2 miles in a cylinder above the molybdenum-bearing alaskite intrusion. Although weaker at longer distances from the source intrusion, this system extended laterally over 5 miles from its upper levels (Larson and others, 1994a). This hydrothermal system changed, to various degrees, the chemistry and mineralogy of all the rocks that it migrated through, especially along fractures and other permeable zones. *This includes all the rocks now outcropping or present nearby in the subsurface within the Town of Rico.* Rico's lead-zinc-silver ore deposits and subeconomic mineralized zones that also contain these metals are part of the chemical and mineralogical changes produced by this hydrothermal system. This is the part of Rico's geologic history that is tied to the evolution of the San Juan Volcanic Field, and ultimately the Rio Grande Rift to the east.

Before focusing on the geology of the Town of Rico itself, one other aspect of the Rico district needs to be described. Carbon dioxide gas has long been known to be present in Rico area rocks. This gas, heavier than air, is observed as bubbles in springs along the Dolores River and as bad air zones in underground mine workings. Carbon dioxide concentrations in low areas around springs or mine openings have been hazards for small animals and birds who inadvertently entered them and suffocated (Ransome, 1901; McKnight, 1974). Exploration drilling in the Newman Hill area has twice encountered strong flows of carbon-dioxide that presented significant safety hazards (McKnight, 1974; Bielak and others, 1981). There is also a thermal groundwater system in the Rico area. Exploration drilling in the 1980's encountered hot waters that are still flowing through drill holes to the surface today. These hot waters are calcareous and they deposit aprons of calcareous tufa where they flow onto the surface. They may be small examples of what was a recent but prehistoric and very large calcareous spring system on the lower slopes just west of the Dolores River and Rico (Qtu unit of Figure 2-10).

Large amounts of natural carbon dioxide form from the breakdown of limestone (and other calcareous rocks) that accompanies thermal recrystallization. Circulating meteoric water can migrate to deep depths and become heated and long-lived zones of structural weakness with different periods of reactivation, such as the Rico area, are favorable for heating of meteoric water by deep circulation. However, it may be that Rico continues to be a locus of high heat flow and that thermal recrystallization and hydrothermal system development has continued or been regenerated. Regardless, Rico's present characteristics including the active thermal springs and groundwater system, the recent large calcareous spring systems on the west side of Rico, and the widespread and voluminous carbon dioxide in bedrock provide insight into the size and complexity of what was a much more significant time of hydrothermal activity and thermal metamorphism 3 to 5 Ma ago. The 3 to 5 Ma event was a major impact on all the rocks, at the surface and at depth, in the Rico area.

2.5.6.4 Town of Rico Geology

The Town of Rico has several components of its bedrock geology that reflect aspects of the district-scale relations outlined above. In addition, the Rico townsite is primarily developed on young (Quaternary: less than 2 Ma years to present day) surficial materials that are unconformably deposited on all other geologic units (Figure 2-11). Because the bedrock geology directly influences the character of nearby surficial materials in many cases, it will be reviewed first. In the Town of Rico, the exposed bedrock geology includes stratigraphic, igneous, structural, and hydrothermal (ore deposits and associated alteration and mineralization) components.

2.5.6.4.1 Bedrock Geology

Figure 2-10 shows that the principal area in Rico where bedrock is at or near the surface in the north part of town; east from the Atlantic Cable mine area at the intersection of Glasgow Avenue and Soda Streets and north of Silver Creek. **This area of near-surface bedrock includes the area of the Grand View smelter. The Grand View smelter site is located near the east-west trending axis of the Rico structural dome and the adjacent bedrock here is the oldest geologic unit in the area, the Precambrian basement greenstone (Figure 2-11). Displacements along two east-west fault systems, the Last Chance and smelter faults (Figure 2-10), have uplifted the block of basement greenstone at the Grand View smelter site relative to younger bedrock geologic units to both the north and south.** The bedrock geologic units south of the basement greenstone block and north of Silver Creek are those that are exposed near the surface within the present residential area of Rico. The bedrock in this part of Rico is very important because it contains units that preferentially localized sulfide mineralization, including the ore deposits of the Shamrock, Atlantic Cable, and Van Winkle mines.

A more detailed map of the bedrock geology in the northeast part of Rico is presented in Figure 2-12. This map shows the near-surface location of three important bedrock units, the Leadville Limestone, the lower part of the Hermosa Formation, and intrusions of latite porphyry. The Leadville Limestone was thermally recrystallized (marbleized) at the time of latite porphyry intrusion (McKnight, 1974). Because this limestone contained impurities such as quartz and clay minerals, the thermal recrystallization produced new calcsilicate minerals such as garnet, pyroxene, epidote, and tremolite that are now irregular clumps and pods in the host marble (Figure 2-13). This marble, a stratigraphic interval 100 to 200 feet thick, dips moderately (15 to 40 degrees) to the southeast under the northeast part of Rico (Figure 2-12). The lower Hermosa Formation is primarily a clastic-rich section of sandstone, siltstone, and shale with minor limestone or dolomite layers. It makes up about half of the area of near-surface bedrock exposure in the northeast part of town. These rocks were thermally recrystallized along with the other sedimentary rocks of the area but they have also been hydrothermally altered and mineralized later (Figure 2-14). Most of the remaining bedrock of this area is latite porphyry intrusions (sills) that are along or parallel to the layering in the host sedimentary rocks although in some places they are dikes that crosscut the host rock layering. The original textural and compositional homogeneity of latite porphyry has made it very helpful in defining the changes that accompanied the 3 to 5 Ma hydrothermal alteration and mineralization throughout the area (Larson and others, 1994a; 1994b). These rocks make up a large portion of the bedrock on the upper slopes of Knob Hill where they are highly fractured and strongly mineralized (Figure 2-15). Mineralization includes sulfide-bearing fractures and thin quartz-sulfide veinlets; pyrite is widespread and some of the sulfide-bearing veinlets contain visible galena (Russ, 1996). The fairly disseminated

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DOCUMENT DESCRIPTION:

FIGURE 2-12 - GEOLOGICAL MAP

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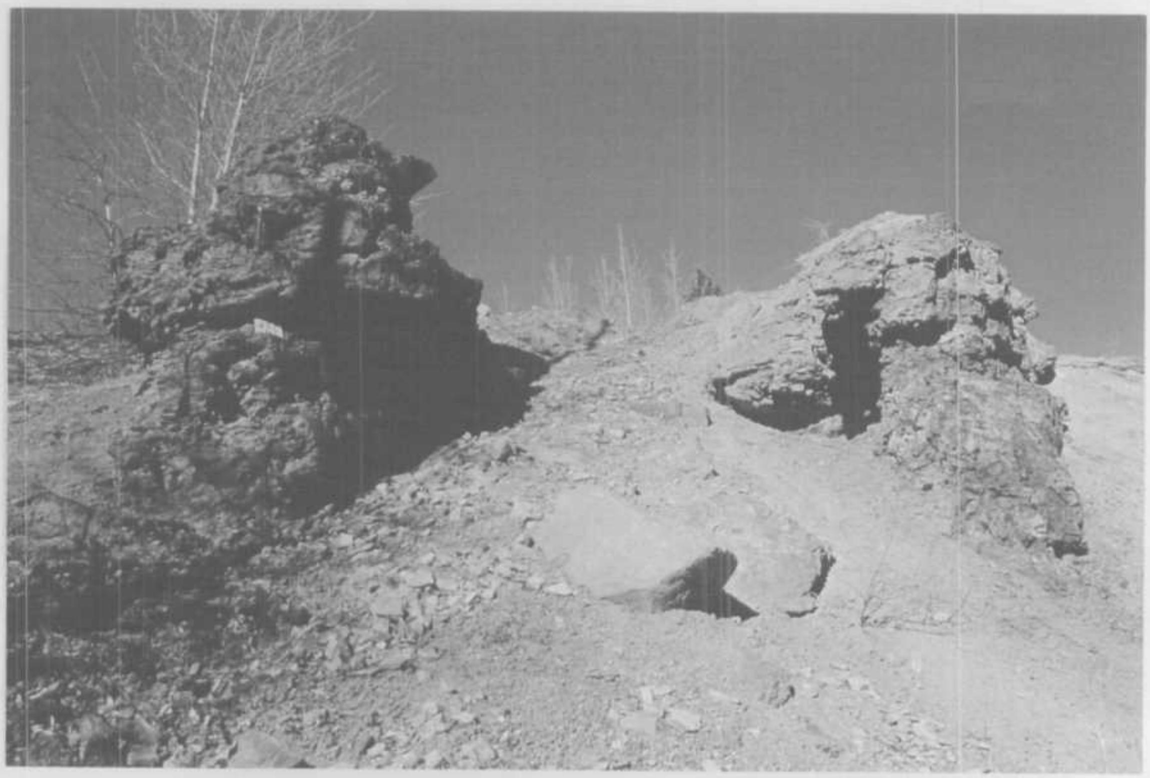
Sample 904: Leadville Limestone Outcrop

Sample 902: Leadville Limestone Outcrop

FIGURE 2-13. Photographs of Leadville Limestone Outcrop.

Sample 916: Hermosa Formation, Lower Member (Sandstone) Outcrop



Sample 921: Hermosa Formation, Lower Member (Shale) Outcrop

FIGURE 2-14. Photographs of Hermosa Formation Outcrop.

Sample 920: Hornblende Latite Porpyry Outcrop

Sample 910: Hornblende Latite Porphyry Outcrop

FIGURE 2-15. Photographs of Latite Porphyry Outcrop.

character of hydrothermal alteration and mineralization in the lower Hermosa and latite porphyry rocks contrasts with that in the Leadville Limestone. Mineralization in the Leadville is much more concentrated and localized in comparison to the other rocks. In fact, it is here that concentrations are high enough to meet economic grades and form ore deposits.

There are two principal ore deposits in the northeast residential area of Rico. These are the irregular sulfide replacements in the Leadville Limestone mined at the Atlantic Cable and Van Winkle mines. Figure 2-12 shows the surface projections of the underground workings of the Atlantic Cable and Van Winkle mines as compiled by Russ (1996) from original mine maps now in the files of Rico Properties, L.L.C. At the Atlantic Cable mine, the shaft (Figure 2-2) was originally sunk on outcropping sulfide mineralization (Ransome, 1901). This deposit was mined from the surface to a depth of 183 feet and workings were developed at three levels (Varnes, 1944, as summarized in McKnight, 1974). This ore body was irregular in detail but overall seemed to be developed along a zone of northwest-trending fractures (Anaconda geologists also interpreted the karst zone at the top of the Leadville to be an important control on ore body development in this area, Bielak and others, 1981). It consisted of pods of galena, sphalerite, chalcopyrite, and pyrite interspersed through a specularite, magnetite, and chlorite assemblage replacing, with sharp contacts, the host marble. The Van Winkle ore body was apparently similar but it was a little deeper being structurally downdip from the Leadville-bearing ore body at the Atlantic Cable. Mine maps indicate that this ore body was developed from a depth of about 200 feet below the surface and it was not directly under the Van Winkle shaft (Figure 2-3) but to the west about half way to the Atlantic Cable deposit. The underground workings of these two mines, and probably those of the Shamrock mine as well, were all interconnected at one time. These ore bodies show that significant lead-, zinc-, and silver-bearing solutions migrated upward into the presently outcropping and near-surface bedrock units in the northeast part of Rico.

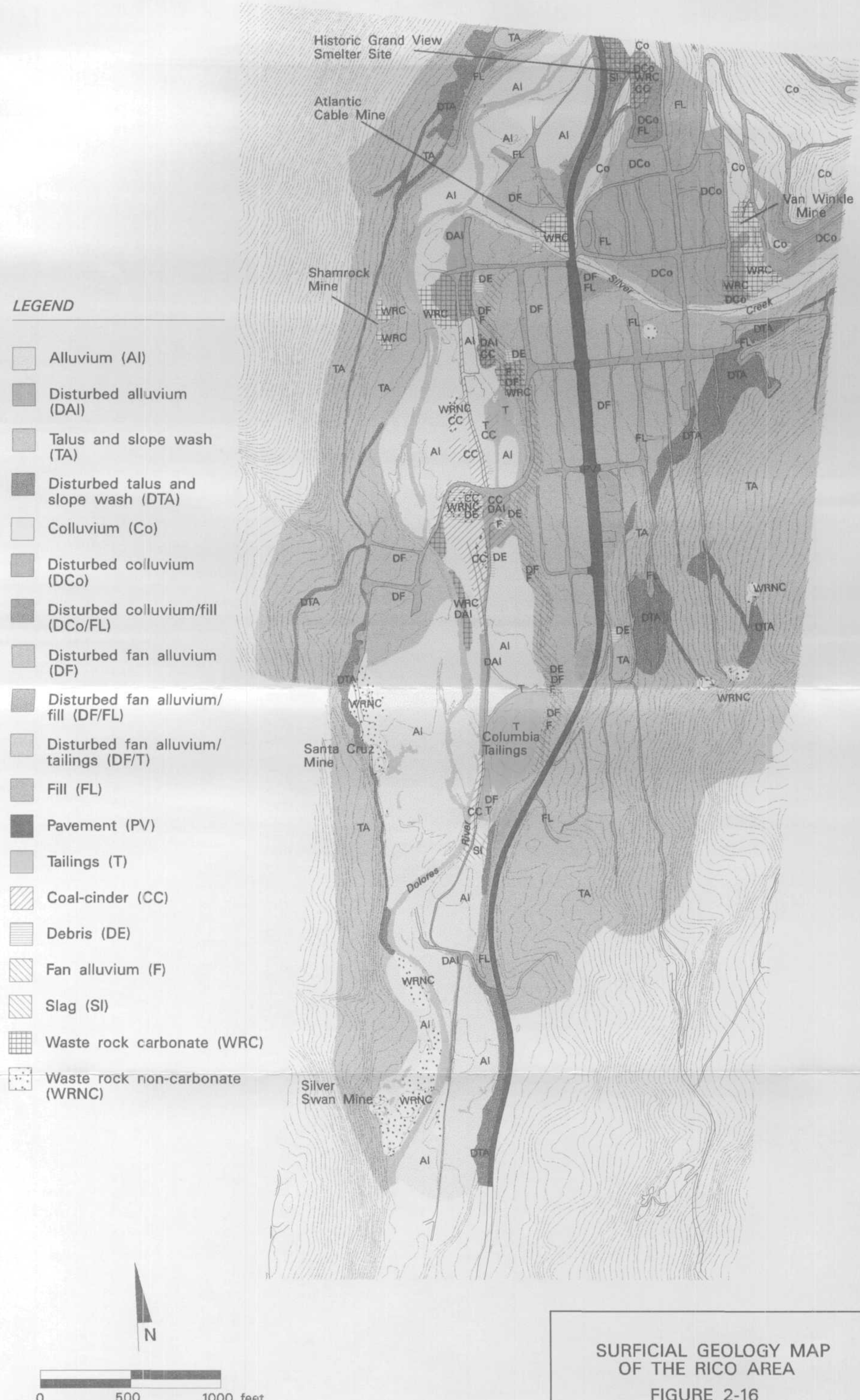
2.5.6.4.2 Surficial Geology

Figure 2-10 shows that a relatively small part of the Rico town area has bedrock at or near the surface and that most of the town, and immediately nearby areas, is covered by young unconsolidated surficial deposits. At the district scale of Figure 2-10, there are three types of surficial materials that have been mapped. These include (1) alluvium (map unit Qal, Figure 2-10) of the active drainages such as the Dolores River, (2) older alluvial fans (torrential fans, map unit Qf, Figure 2-10) deposited where tributaries enter the Dolores River valley (Rico is largely developed on one of these), and (3) talus and slope wash (map unit Qtw, Figure 2-10) deposited on steeper slopes to both the east and west of Rico. The surficial processes producing these materials involve the weathering of bedrock exposures at higher elevations, transport of a surface mantle of weathered debris downslope to the stream drainages, and reworking of the transported debris by the ancestral and active streams. In this sequence of weathering, surface transport, and stream reworking there is one surficial component that is not illustrated in Figure 2-10. In some places, where slopes over bedrock are low to moderate, the weathered bedrock material can form an in situ mantle of unconsolidated material, colluvium, that has not been significantly transported relative to its nearby bedrock sources. One such area is the northeast part of Rico where bedrock is at or near the surface.

Figure 2-16 is a more detailed map of the surficial geology in the Rico area. This map (PTI, 1995) was specifically made to show the distribution of surficial materials in the Town of Rico. It is different from Figure 2-10 in two important ways; (1) three separate alluvial fans (Iron Draw, Silver Creek, and ancestral Silver Creek) are identified rather than just one (ancestral Silver Creek), and (2) a colluvial mantle is mapped over the northeast part of town rather than bedrock (this is explained below). This map also identifies the larger areas of other surficial materials such as road fill, mine wasterock, and mill tailings and thereby serves to distinguish the areas dominated by natural materials from those that are anthropogenic. The natural materials are the major surface units of Figure 2-16 and include talus and slope wash deposits on both the east and west sides of town, alluvium of the active Silver Creek and Dolores River drainages (mostly the river corridor area), the three alluvial fans mentioned above, and the colluvial mantle in northeast Rico. All are described more completely below.

Talus and slope wash: These unconsolidated deposits are present on the moderate to steep slopes to both the east and west of the lower areas along the Dolores River and Silver Creek. These materials are very poorly sorted mixes of mud, silt, and abundant coarser angular rock fragments that are in slow migration down the slopes from their bedrock origins. Weathered debris from the underlying bedrock is incorporated as the unconsolidated mass moves slowly downslope. These materials have a diverse assemblage of lithologies because of their transported character. The thickness of this material can vary tremendously. It is commonly a few to tens of feet thick but in some areas such as Newman Hill, it can be up to 400 feet thick (Rickard, 1897; Ransome, 1901).

Alluvium: The valley of the Dolores River and the relatively narrow active stream channel of Silver Creek contain deposits of alluvial gravels. These materials are only moderately sorted silt, sand, pebbles, cobbles, and boulders. They are coarse in texture and, being extensively re-worked and highly transported, very diverse in lithology. Areas peripheral to the active stream channels in the Dolores River floodplain contain more silt and sand and, in many places, organic-rich wetlands developed on top of the alluvium (Figure 2-7).



SURFICIAL GEOLOGY MAP OF THE RICO AREA

FIGURE 2-16

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Alluvial fans: Alluvial fans have formed where tributaries enter onto the Dolores River floodplain. The tributaries, Silver Creek and Iron Draw within the town of Rico, have small headwater areas and steep hydraulic gradients compared to the Dolores River and transport much coarse and poorly sorted gravel, particularly at times of high runoff (Figure 2-5). These deposits are a mix of silt, sand, pebbles, and gravel containing abundant cobbles and boulders.

These coarse sediments are rapidly deposited because of the significant decrease in stream gradient that occurs where the tributaries merge with the Dolores River valley. These sediments form aprons or fan-like deposits that spread out onto the Dolores River floodplain at the mouths of the tributaries. There are three such alluvial fans in Rico; (1) the alluvial fan that is being actively deposited and reworked at the mouth of Silver Creek, (2) a small alluvial fan at the mouth of Iron Draw on the west side of the river, and (3) a large ancestral alluvial fan at the mouth of Silver Creek. The ancestral alluvial fan was formed at an earlier time when Silver Creek and the Dolores River were both graded to a higher base level. It is incised by the present floodplain of the Dolores River and the steep banks on the east side of the floodplain, which cut into this ancestral fan, show that these deposits can be more than 75 feet thick. The alluvial fans are important in Rico because they have gently sloped surfaces above the flood levels of the Dolores River. As such, they have been the favored areas for residential and other development in the town.

Colluvium: Figure 2-16 shows that the northeast part of Rico, where bedrock is at or nearby the surface (Figure 2-10) is mantled by colluvium. Colluvium is weathered rock debris developed on top of bedrock. It differs from talus and slope wash by not being significantly transported. It is proximal to the bedrock from which it is derived and therefore contains lithologies that directly reflect the adjacent bedrock As illustrated in Figure 2-17, the zone of weathered, unconsolidated material on bedrock can be several to tens of feet thick in northeast Rico. This material is poorly sorted mud, silt and angular rock fragments of all sizes up to boulders (Figure 2-17). The colluvial-mantled part of Rico is also characterized by having well-developed soil horizons in undisturbed areas (Figure 2-17). This suggests that the colluvium surface in northeast Rico is one of the older geomorphic surfaces of the area.

Because of the importance of understanding the relation between bedrock and the surficial materials in northeast Rico, a detailed surficial map was made of this area (Russ, 1996). This map, Figure 2-18, shows the distribution of bedrock outcrops and three different categories of colluvium; (1) colluvium dominantly containing fragments of Leadville Limestone, (2) colluvium dominantly containing fragments of latite porphyry, and (3) colluvium containing a mix of lithologies, primarily clastic rocks and latite porphyry. This map also distinguishes disturbed and undisturbed colluvium as well as other kinds of surficial materials in the area such as road fill and

Sample 943: Mixed Quarternary Colluvium - Undisturbed

FIGURE 2-17. Colluvial Mantle on Bedrock.

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FIGURE 2-18 - SURFICIAL GEOLOGY MAP

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mine wasterock. The disturbed colluvium is identified in those areas where anthropogenic impacts such as foundation excavations, utility excavations, and surface grading have taken place. Generally these activities have resulted in the moving and mixing of the local colluvium with little or no addition of other materials.

It may be helpful to explain how a bedrock geologic map such as Figure 2-10 and 2-12 can be made in an area of colluvial cover such as northeast Rico (Figures 2-16 and 2-18). In such areas, the near-surface distribution of bedrock units can be projected from limited bedrock exposures because other information about the units and their relations to one another are known. For example, the thickness' and successions of the sedimentary formations are known from other exposures in the Rico area. Upon knowing the structural attitude of these formations in local outcrops, projections through covered areas are straight forward. Discontinuities in the expected relations indicate the presence of faults that structurally disrupt the bedrock units. In addition, the locally derived character of colluvium helps to predict the subjacent bedrock geology. In general, in areas of variably thick colluvium with interspersed outcrop, the principal bedrock relations can be mapped as they have been in northeast Rico (also see McKnight, 1974, p. 32).

Other surficial materials: **Figure 2-18 also shows the distribution of man-made areas of fill, mine waste rock, and other materials including a small area of exposed slag-rich material at the old Grand View smelter site near Highway 145 at the north edge of the map.** In general, these materials are discrete localized occurrences that can be individually mapped. **In the case of the Grand View smelter, the general site area is now dominantly disturbed colluvium over greenstone basement rocks (see also Figures 2-10 and 2-16). The disturbance in this area is most recently the result of surface grading that accompanied demolition and burial of remnant facilities and waste materials in 1993 (see above). Figure 2-7 helps illustrate the present surface character of this area.**

2.5.6.5 Mineralogy

Representative samples of the bedrock and surficial units of northeast Rico have been the focus of a detailed mineralogical study to further characterize these materials and clarify their relations to one another (Geomega, 1996). Figure 2-19 shows the linkages between the ultimate source of metal-bearing materials, bedrock, and the surficial materials within the Town of Rico. The surficial materials are divided into those that are derived from the natural weathering of bedrock (colluvium and related materials) and those that derive from the mining of bedrock. Small amounts of ore concentrates have been processed at the Grand View smelter site and probably at the Pasadena smelter site (RGS Coaling Facility, see Appendix B), but most ore concentrates were shipped elsewhere for smelting. Mine waste rock is present locally in Rico such

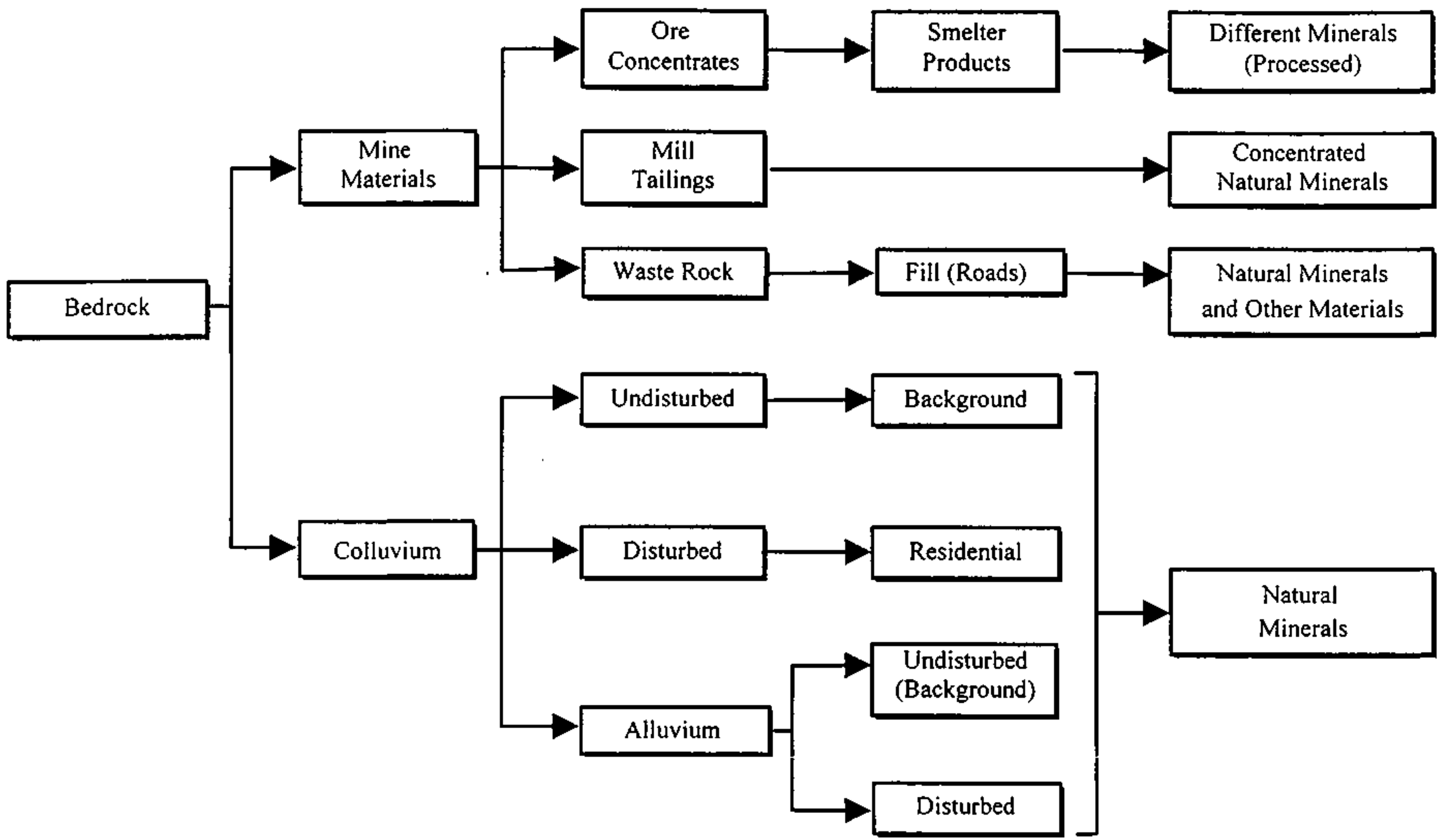

FIGURE 2-19

Diagram Showing Minerologic Linkages Between Bedrock and Soils

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as at the Atlantic Cable and Van Winkle mines. From time-to-time mine waste rock has been a source of fill material for roadbeds in the area.

A key relationship illustrated in Figure 2-19 is that all surface materials that derive for the natural weathering of bedrock contain assemblages of natural minerals. Waste rock and mill tailings are concentrated assemblages of natural minerals but, the processing of ore concentrates by smelting produces mineral assemblages that are different from their natural parents.

Thirteen samples were selected for detailed mineralogical analysis to confirm and define more accurately the general relationships illustrated in Figure 2-19. These samples, listed in Figure 2-20, are from bedrock, colluvium, alluvium, mine waste rock (Van Winkle mine), roadfill, and smelter wastes (Grand View smelter site). This mineralogy study was completed by Geomega and analytical procedures, sample descriptions, and more detailed sample results are given in their report which is provided separately with this application.

Figure 2-20 lists the proportions of the identified lead-bearing minerals (phases) in each sample. The lead-bearing minerals are primary (galena - PbS - the principal lead mineral in non-weathered Rico mineral deposits), secondary (anglesite and cerrusite which derive from the oxidation of galena), tertiary (primarily iron-lead and manganese-lead oxides derived from the dissolution, hydrolysis, and complexing of primary and secondary lead-bearing phases), and anthropogenic phases such as solder and slag that are produced by man's activities and are not natural minerals.

Figures 2-21 and 2-22 are photomicrographs of Rico samples that show the spatial and genetic relations that can develop between natural phases as the chemical reactions accompanying oxidation and weathering proceed and the evolution for primary to tertiary mineral assemblages takes place. Some of the general chemical reactions that control the evolution of these phases include the following:

Galena (Primary)		Anglesite (Secondary)
$PbS + 2O_2$	=	$PbSO_4$
Anglesite (Secondary)		Cerrusite (Secondary)
$PbSO_4 + HCO_3$	=	$PbCO_3 + H^+$
Cerrusite (Secondary)		Plattnerite (Tertiary)
$PbCO_3 + H^+ + O_2$	=	$PbO_2 + HCO_3 + 2e^-$

		Primary	Secondary		Tertiary							Anthropogenic				
Sample Number	Sample Type	Galena	Anglesite	Cerussite	FePb Oxide	MnPb Oxide	Pb Phosphate	FePb Silicate	FePb Sulfate	Pb Organics	Pb Silicate	Pb(M)O	Slag	Solder	Paint	Occurrence
906	Bedrock	42 1	37.9	7.6	10.9	0.4	0.4	*	*	*	*	*	*	*	*	Dominated by galena and anglesite
910	Bedrock	0 9	6	81	6	3.3	0 75	*	*	*	*	*	*	*	*	PbCO3 is dominant Pb phase
917	Bedrock	18.4	21.9	46.4	10.2	0.99	*	*	*			*	*	*	*	Cerussite and anglesite rich
932	Colluvium	0.13	*	*	32.2	18.1	*	24.6	*	8.2	*	7 6	7.2	1	*	Fe and Mn oxides dominant; lesser FePb silicates
938	Alluvium	1 1	0.3	7 7	41 6	26.3	15 7	*	*	*	6.4	*	*	0.66	*	Fe and Mn oxides dominant
939	Alluvium	*	*	6 5	4.7	21.3	1 4	65.2	*	*	*	0 65	*	*	*	FePb silicates are main Pb phase
940	Alluvium	0 6	*	0 5	29.9	43.8	2.7	14.1	6.7	*	0.97	0.7	*	*	*	Tertiary phases dominant, esp oxides
943	Colluvium	15 1	13.8	42 9	21 5	*	*	6.7	*	*	*	*	*	*	*	Cerussite and FePb oxides
945	Colluvium	*	0.4	0 9	6 6	6 1	*	84	*	*	*	*	*	*	*	Dominated by FePb silicates
96-CH-01	Grand View	0 3	2 7	*	0 2	0 2	*	*	0.8	*	*	*	94	*	*	Slag
96-CH-02	Roadfill	22.6	0 2	3.2	16.4	5.8	0.5	22.6	1 2	*	*	0.7	26.5	*	0.5	Equal mix of primary, secondary, tertiary, anthropogenic
96-CH-03	Van Winkle	17 5	2 9	22 5	21.2	35.1	*	0.6	*	*	*	*	*	*	*	Mix of primary, secondary, and tertiary phases
96-CH-04	Roadfill	19 8	*	12	31 4	25 2	1.1	1.2	0.8	*	*	0.1	8.4	*	*	Dominated by tertiary oxides, with lesser primary/secondary

* Not detected

Figure 2-20. Frequency of Occurrence of Pb Phases in Rico Samples

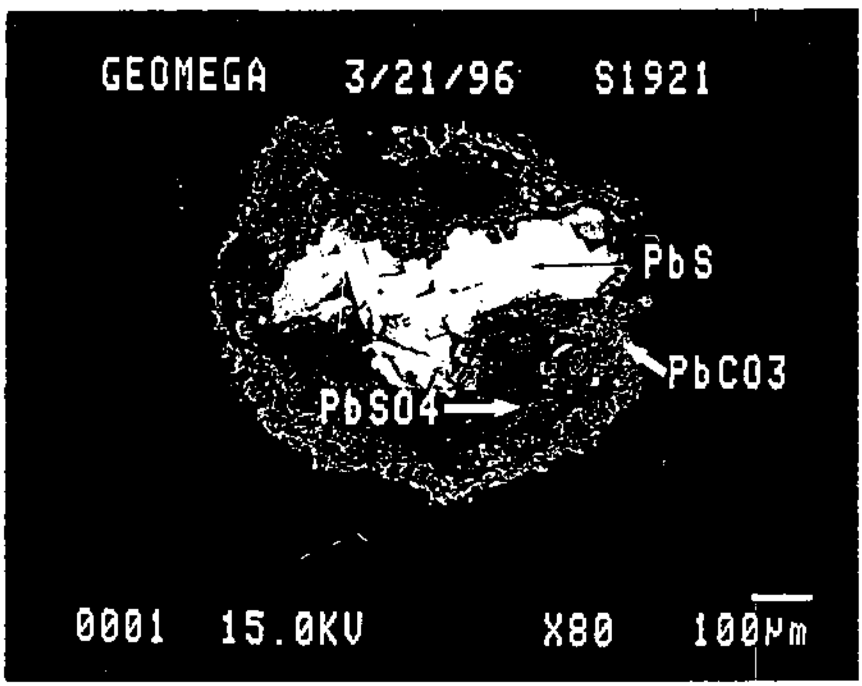

Figure 2-21. Photomicrograph showing paragenetic relationship between primary Pb phase (galena-PbS) and secondary Pb phases (anglesite-$PbSO_4$ and cerussite-$PbCO_3$). Galena oxidizes directly to $PbSO_4$ which then converts to $PbCO_3$ in response to alkaline pH conditions. (Sample is from Van Winkle mine site).

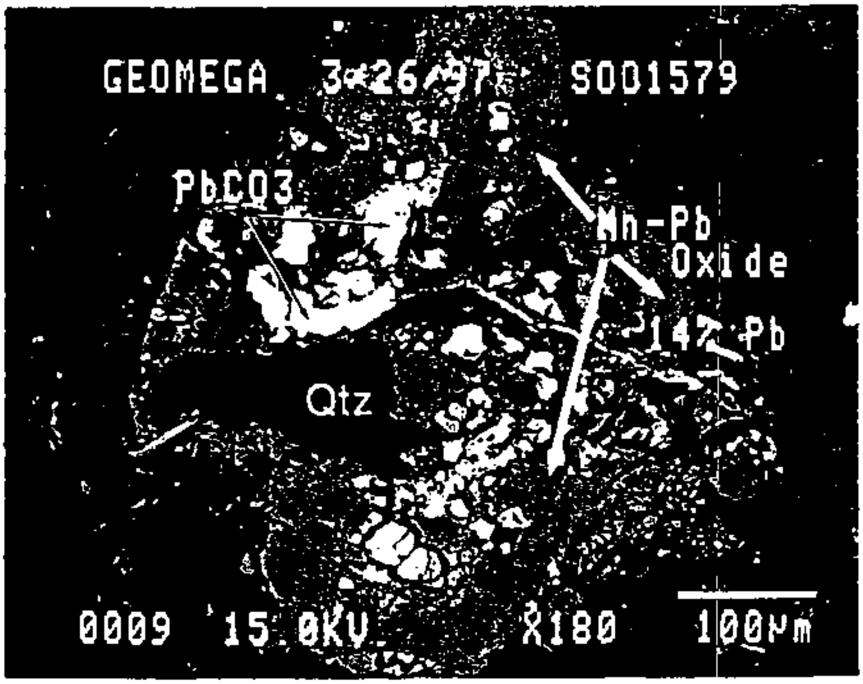

Figure 2-22. Photomicrograph of tertiary phase MnPb oxide precipitate encapsulating secondary phase $PbCO_3$ grains. As $PbCO_3$ is subjected to dissolution, Pb^{+2} ions are scavenged and coprecipitated by Mn oxides. (Sample is from 6-8' depth in Quarternary alluvium).

This evolution of lead-bearing mineralogy, for primary to tertiary assemblages, is characteristic of the natural weathering processes in lead-mining areas (see Table 3-29; Section 3.7.3).

Figure 2-23 shows the relative proportions of primary + secondary, tertiary, and anthropogenic mineral assemblages in specific samples. This diagram illustrates that the only sample from the Grand View smelter site is dominated by anthropogenic lead phases (in this case slag, Figure 2-20). The two samples of roadfill have mostly natural primary, secondary, and tertiary mineral assemblages, but some slag is also present in them (Figure 2-20). There is only one sample of natural materials (disturbed colluvium, sample 932) that contains some anthropogenic material. This sample contains 7.2 percent slag and 7.6 percent of a lead-metal-oxide phase common in smelter wastes (Geomega, 1996). This sample is from a utility right-of-way adjacent to Silver Street, the same street for which sample 96-CH-04 was collected. This sample shows that some areas adjacent to roadfill may have low concentrations of anthropogenic lead phases mixed in with the natural lead phases.

The remainder of the samples in Figure 2-23 plot along or close to the primary + secondary/ tertiary side of the diagram indicating low to absent anthropogenic components. This confirms the dominance of natural lead-bearing mineral assemblages in the colluvium and alluvium, upon which most of Rico is developed. In addition, note that the transition from bedrock (samples 906, 910, and 917) to intermediate depth colluvium (six to eight feet deep, sample 943), to surface colluvium (samples 932 and 945), illustrates the evolution from primary to tertiary mineral assemblages. The surface environment is where oxidation, hydrolysis, and complexing reactions can be most complete as evidenced by the dominance of tertiary mineral assemblages in surface samples (0 to 12 inches).

In summary, the mineralogy data confirms the dominance of natural mineral assemblages in Rico surficial materials. These assemblages derive from the original minerals in bedrock through chemical reactions that accompany weathering processes, primarily oxidation, hydrolysis, and complexing. Some anthropogenic materials, related to smelting, are present in roadfill but only one sample, from the Grand View smelter site, is dominantly anthropogenic with respect to its lead-bearing phases. The data for the Grand View smelter site (sample 96-CH-01, Figure 2-20) show that there is almost no natural lead-bearing phases present here. This strongly contrasts with what has been found in all the other samples of surficial materials of the area (Figure 2-23).

Bedrock	(906, 910, 917)
Colluvium	(932, 943, 945)
Alluvium	(938, 939, 940)
Roadfill	(96-CH-02, 96-CH-04)
Mine Waste Rock	(96-CH-03, Van Winkle)
Smelter Waste	(96-CH-01, Grand View)

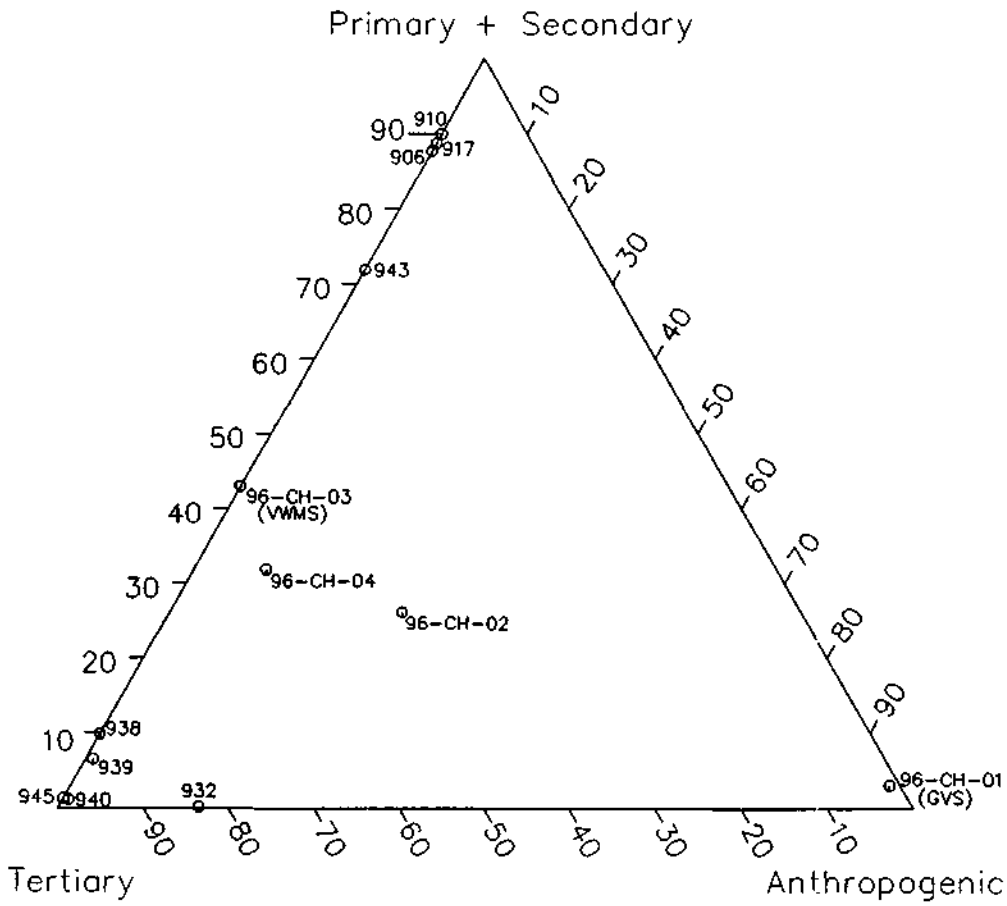

Figure 2-23. Ternary diagram showing relationship between Primary + Secondary, Tertiary, and Anthropogenic Pb phases in Rico Samples based on frequency of occurence.

2.5.6.6 Summary

The geologic framework presented above clarifies four very important general characteristics of the Rico area:

(1) Bedrock in the entire Rico town area was significantly impacted by an extensive hydrothermal system that developed upon emplacement of a molybdenum-bearing alaskite stock about 3 to 5 Ma ago near where the Blackhawk fault crosses Silver Creek (Figure 1-2). This hydrothermal system flushed all the bedrock in the area and caused extensive alteration and mineralization. Structural and stratigraphic controls on the intensity of this alteration and mineralization resulted in areas of extensive veining and replacement including the formation of economic lead-, zinc-, and silver-bearing ore bodies such as those in the area of the Atlantic Cable and Van Winkle mines.

(2) Lead-, zinc-, and silver-bearing mineralization crops out at the surface in Rico. The most obvious example is the Atlantic Cable ore body but basically all bedrock in the town area is mineralized (also see below).

(3) The town of Rico is developed on natural surficial materials eroded from variably mineralized bedrock sources. These materials include colluvium nearby to bedrock, transported talus and surface wash, and alluvial deposits. In developed areas, these materials have primarily been disturbed by excavation- and grading-related activities.

(4) The principal mining-related materials, such as mine wasterock, mill tailings, and smelter slag, can be distinguished from natural surficial materials. Maps showing the distribution of these mining-related materials indicate that they are discrete, localized, and much less extensive in their distribution than natural materials.

2.5.7 Physical Characteristics of Surficial Materials

Relevant physical characteristics of the various surficial materials are summarized below.

Alluvium: Both active and ancestral alluvial deposits are unconsolidated and coarse in texture. Because of their relative youthfulness, soils are poorly developed. Pebbles, cobbles and boulders can be exposed at the surface as vegetation, except in wetlands, tends to incompletely cover the surfaces. Residential yards on this material have commonly been raked to consolidate or remove the coarser surface material and help grass cover develop.

Talus and slope wash: These materials are unconsolidated and very rocky. Vegetation, including meadows and woodlands (see above), commonly covers at least 50% of their surfaces and an organic-rich soil can be present. Larger rock fragments are commonly exposed on the surface. Residential development has disturbed these materials by excavation and grading where necessary but otherwise they tend to be left in their natural state.

Colluvium: These materials have characteristics somewhat like that of talus and slope wash; unconsolidated, rocky materials that have moderate vegetation cover, organic soil development, and some coarser rock fragments exposed at the surface. In residential areas, they have been graded, raked and otherwise disturbed as well as left in their natural condition.

Mine wasterock: Piles (dumps) of mine wasterock are scattered throughout the Rico district and examples have been described in other VCUP applications (Silver Swan and Santa Cruz mine sites). Those in town are associated with the Atlantic Cable, Shamrock, and Van Winkle mines. The dumps here differ from those at the Silver Swan and Santa Cruz mines in that they contain a high proportion of limestone. The buffering capacity of this limestone inhibits the oxidation of sulfide minerals (mainly pyrite) and the corresponding development of acidic conditions within the dumps or the waters draining through them. The surfaces are rocky and only sparsely vegetated if at all (mostly with clumps of small aspen and spruce).

Mill tailings: Mill tailings are present at two locations in the Rico area and both are addressed in other VCUP applications (Argentine and Columbia tailings). Neither are in areas of existing or planned residential development.

Smelter wastes: **At the Grand View smelter, extensive reworking by later activities such as road construction and purposeful burial, has left a small patch of exposed smelter waste. These fine- to coarse-textured materials are a varied mixture of remnant sulfide minerals, oxidation products from the roasting of sulfide minerals, cinders, incompletely burned organic materials, refractory minerals, and glassy slag. The surface over about a one acre area surrounding the slag-rich patch is mostly bare, rocky disturbed colluvium (Figures 2-8, 2-16, and 2-18).**

Remnants of the old Grand View smelter facility (timbers, machinery, roasting pots, etc.) were combined with most of the accumulated onsite, slag-rich material and previously buried (1993) at the location shown on Figure 4-1 (in Section 4.0). The surface of this buried area was covered and reclaimed (Figure 2-8). Much of this same area will be further covered with construction of the proposed Highway 145 access road (Figure 4-1).

Other surficial materials: Most other surface materials that are extensive enough to be identified and mapped separately (Figure 2-16), are associated with the old Rio Grande Southern Railroad facilities that were primarily developed along the river corridor (Figure 2-1 and 2-16). The water tank visible in Figure 2-1 is still standing but otherwise the obvious remains of the railroad are limited to sections of the railroad grade now being used as a dirt road along the river corridor. Throughout this area, surface materials containing bits of coal and cinders mixed in with gravel and other fill materials are common. This entire area is planned to be part of a river corridor set aside for open space (Figure 2-4).

Other physical characteristics information requested by VCUP include the following list of facilities or systems. Some of these are present in Rico but they are not applicable here because they do not exist at the Grand View smelter site where remedial actions are proposed:

"*(iv) facility process units and loading docks;*
(v) chemical and/or fuel transfer, and pumping stations;
(vi) railroad tracks and rail car loading areas;
(vii) spill collection sumps and/or drainage collection areas;
(viii) wastewater treatment units;
(ix) surface and storm water run-off retention ponds and discharge points;
(x) building drainage or wastewater discharge points;
(xi) all above or below ground storage tanks;
(xii) underground or above ground piping;
(xiii) air emission control scrubber or refrigeration units;
(xiv) water cooling systems or refrigeration units;
(xv) sewer lines;
(xvi) french drain systems;
(xvii) water recovery sumps and building foundations;
(xviii) surface impoundments;
(xx) chemical or product storage areas;
(xxi) leach fields; and
(xxii) dry wells or waste disposal sumps."

2.5.8 Aquifers

Ground water occurs in two flow systems in the Rico area: shallow unconfined ground water in surficial deposits (e.g., alluvium, and talus/slope wash and fan deposits), and unconfined to semi-confined ground water in bedrock units.

2.5.8.1 Alluvial Flow System

Shallow ground water occurs in the alluvium in the Dolores River valley, alluvial fan deposits that have formed at the mouths of tributary streams such as the Horse Creek and Silver Creek, and in slope wash and talus deposits. Although there are no wells in the Dolores River flood plain, the depth to ground water (water table) is generally expected to be less than 10 feet. For example, the depth to water at the Columbia tailings site on October 20, 1995 and December 15, 1995 ranged from about 5 feet to 8 feet below the natural ground surface. Ground water recharge is by direct infiltration of snowmelt and precipitation, and infiltration from tributary streams where they cross alluvial fan and slope wash deposits. Ground water movement is down slope toward the Dolores River or tributary streams, or into bedrock through complex fracture systems. The Dolores River acts as a drain or line sink for discharge of shallow ground water where ground water discharges either directly to the river or to the wetlands along the river, or is lost through evapotranspiration. The thickness of the alluvium along the river is undetermined, but it is assumed to be less than 50 feet.

2.5.8.2 Bedrock Flow System

Ground water occurs in the bedrock complex that forms the mountain slopes on both sides of the Dolores River valley and underlies the valley fill. Ground water storage and flow in the bedrock system is predominantly associated with complex fracture systems and solution channels in limestone units where such exist. The principal source of ground water recharge is infiltration from streams and unconsolidated surficial deposits (e.g., alluvium and talus/slope wash) and by direct infiltration of precipitation and snowmelt. Water may discharge by hydraulic seepage to streams, surficial deposits, springs, wells, or underground mine workings. Discharge of water from mines that intersect water-bearing fracture systems and mineral veins is a common occurrence in the Rico district and can significantly lower the water table in mined areas. For example, the water level in mines interconnected with the St. Louis tunnel has been lowered by about 450 feet and water continues to be drained from a large block of mineralized ground (McKnight, 1974) with seasonal discharge generally ranging from about 500 gpm to 1,900 gpm (PTI, 1995b). Similarly, on the west side of the Dolores River, the Silver Swan, Santa Cruz and other mines drain a significant block of mineralized bedrock, but with lower seasonal flows than the St. Louis tunnel system. For example, the historic flow data for the Silver Swan mine discharge indicate an average flow of about 50 gpm with a range of no flow to 193 gpm (PTI, 1995b).

2.5.9 Ground Water Monitoring and Supply Wells

" If ground water contamination exists, or if the release has a potential to impact ground water, the Applicant should provide...listing of all wells within the one-half mile radius of the site, together with a map showing the locations of these wells;... "

There are no known ground water monitoring or supply wells in the Town of Rico. As described in Section 2.5.4, there are only two supply wells in use in the Rico area and they are located in the Dolores River valley north of the townsite (Figure 2-6). Three small diameter (2 inch) piezometers (perforated PVC pipe) were installed in alluvium on the perimeter of the Columbia tailings pile in October 1995 to determine the depth to water (see Columbia tailings VCUP application).

2.6 Nature and Extent of Contamination

Data from three recent studies (Walsh, 1995; PTI, 1995a; Russ, 1996) are available to help define the heavy metal contents of bedrock and surficial materials in the Town of Rico.

Walsh Soil Sampling: This sampling effort was conducted by Walsh Environmental Scientists and Engineers, Inc. (Walsh, 1995) as part of a Phase I and Phase II Environmental Assessment for Rico, Colorado, prepared for Rico Renaissance, L.L.C. Forty-eight samples were collected, targeting areas of interest to the development company and attempting to evaluate properties that contained elevated metals concentrations. These areas included waste-rock piles, mill tailings, and fill material. Results from the Walsh study were intended to provide information on specific properties that were being considered for purchase by Rico Investment Corporation, and to identify potential problem areas associated with mine waste. Additional information concerning sample location, concentrations of analytes in soils, maps, and procedures used in selecting and analyzing data collected by Walsh is provided in Phase I and Phase II Environmental Site Assessment, Rico, Colorado (Walsh, 1995). A copy of this report is provided separately.

PTI Soil Sampling: This soil sampling effort was conducted in May 1995 by PTI Environmental Services (PTI, 1995a). Sampling sites were chosen by overlaying a grid on the map of the Town of Rico and randomly selecting locations on the grid. Sample sites that were close to Walsh sites were relocated on the grid to minimize any duplication in coverage. Seventy-three samples of surface materials were collected in this investigation. Additional, detailed information regarding the specific sample locations and analytical procedures are given in PTI (1995) which is provided under separate cover.

TEC Soil Sampling: In October, 1995, Titan Environmental Corporation (TEC) conducted geologic mapping and sampling of surface materials to determine if concentrations of selected metals in surficial deposits are the result of erosion and concentration of naturally occurring geologic sources, or the result of mining activity. A total of 46 samples from both outcrops and unconsolidated surficial deposits were collected and analyzed for arsenic, cadmium, copper, lead, manganese, silver and zinc content. Nine of these samples, and four others collected by Travis Hudson in February 1996, were studied in detail in order to determine the mineralogy of the samples (Geomega, 1996). Descriptions of all of the samples can be found in Russ (1996) and Geomega (1996) which are provided separately.

The data from the three studies, combined here into groups of samples representative of the principal bedrock and surficial units of Figures 2-16 and 2-18, are listed in Tables 2-1 through 2-9. Sample locations are shown in Figure 2-24. Arsenic, lead, manganese, cadmium, zinc, and, in some cases, copper and silver were analyzed for in a total of 136 samples representative of most of the natural and other materials described above The analytical data are discussed separately below for each of the principal bedrock and surficial units.

2.6.1 Bedrock

Analytical data for 24 samples of bedrock are listed in Table 2-1 and shown diagrammaticly in Figure 2-25. The bedrock samples include data for Leadville Limestone, latite porphyry, Hermosa Formation, and quartzite; they were collected from widely scattered outcrops in the northern part of Rico (Figure 2-12). The Leadville Limestone data confirm relationships seen in outcrop (Russ, 1996) and described in the underground ore deposits (see above); sulfide mineralization is present in discrete replacements and less widely disseminated than in the other bedrock units. Two of the samples are highly metallized (samples 913 and 917, Table 2-1). Sample 917 (Table 2-1), with over 2 % lead and 4 % zinc (the highest zinc concentration in all of the bedrock samples), probably contains significant sphalerite thus explaining the high cadmium concentration. The six other Leadville Limestone samples are weakly metallized, especially compared to the samples of the other bedrock units (Figure 2-20). Compared to other bedrock units, these Leadville Limestone samples contain lower levels of arsenic (2.5 to 5.8 ppm), lead (13 to 71 ppm), manganese (177 to 815 ppm), cadmium (0.31 to 1.16 ppm), and zinc (63 to 195 ppm). The arsenic and cadmium levels in these samples are about what would be expected for limestone whereas the manganese content may be a little low (Table 2-10). However, the base metal content of the less metallized Leadville Limestone samples is, on the average, four times or more what is common in limestone. This suggests that even the most impermeable, most weakly metallized bedrock materials in Rico have trace metal signatures that show the influence of the extensive hydrothermal system developed in the area. All of the other bedrock materials in the area clearly do.

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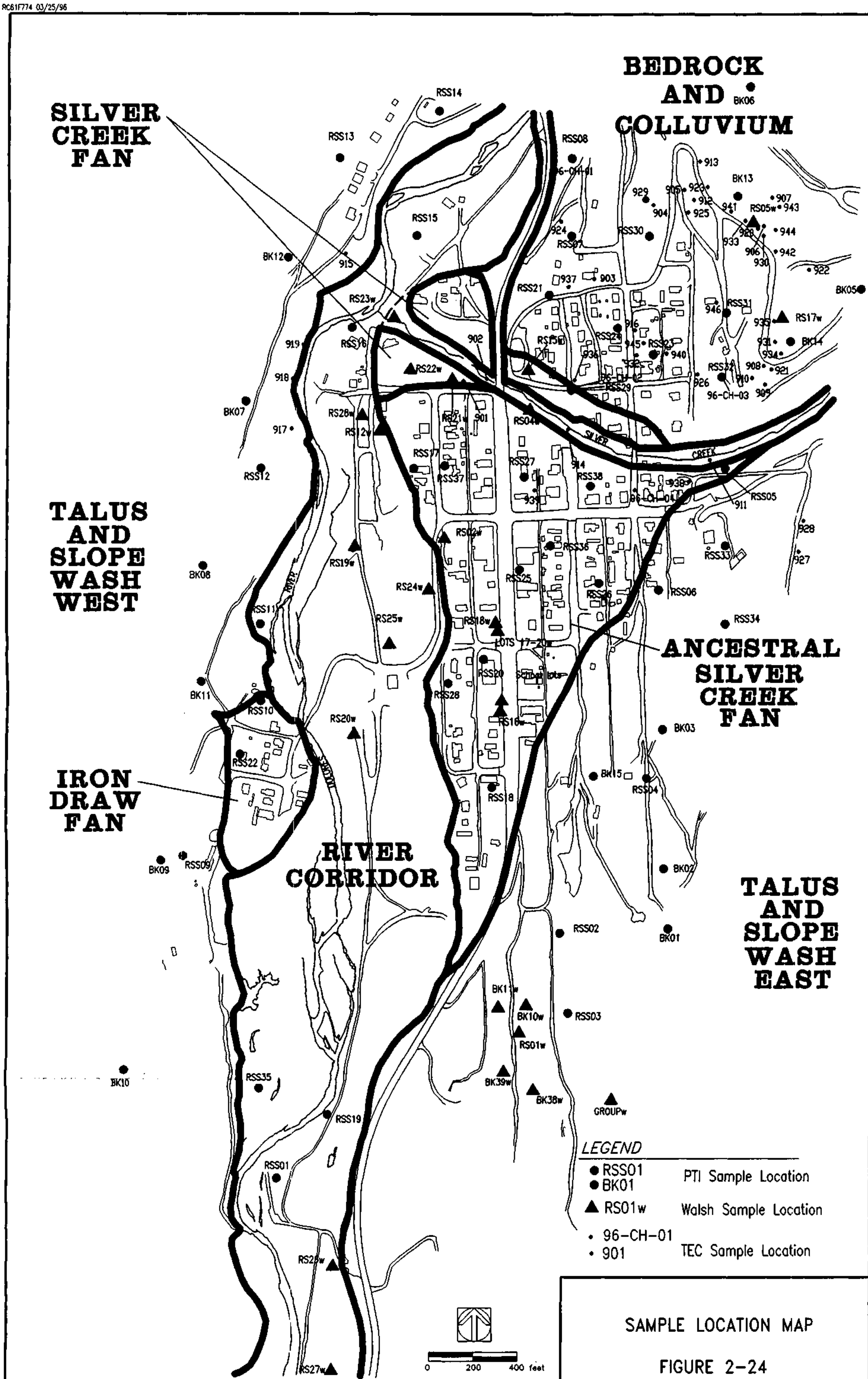


SAMPLE LOCATION MAP

FIGURE 2-24

TABLE 2-1
BEDROCK DATA

SAMPLE NUMBER	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
Leadville Limestone							
901	2.5	71	815	1.16	123	195	0.42
902	2.5	39	378	0.77	90	133	0.42
903	2.5	19	213	0.32	126	63	0.43
904	2.5	13	177	0.32	100	75	0.43
905	2.5	19	337	0.32	91	98	0.43
912	5.8	55	530	0.31	39	108	0.41
913	2.5	1,330	10,800	26.90	32	2,410	2.86
917	9.8	21,200	13,100	322	793	42,500	66.70
Porphyry							
906	13.6	13,600	7,060	1.51	846	881	64.70
909	15.9	2,660	18,800	157	1,640	27,700	29.00
910	9.5	39,700	10,800	79.70	1,370	14,100	60.90
918	11.8	124	652	0.38	900	162	4.55
919	7.9	84	2,070	0.31	430	260	6.97
920	7.6	790	1,400	3.99	55	1,290	0.44
922	51.7	11,400	1,240	15.0	310	2,870	8.18
Hermosa Formation							
907	35.4	691	4,340	13.80	607	2,010	9.25
908	36.4	289	33,200	77.90	271	28,100	1.38
911	13.1	367	1,210	1.87	33	461	0.94
914	2.5	47	468	0.31	231	153	0.41
916	9.8	787	6,170	0.32	132	592	0.96
921	23.4	89	29,300	34.30	109	22,800	0.44
Quartzite							
915	80.2	402	867	0.32	258	243	22.20
923	7.1	242	2,790	0.33	120	266	0.43
924	39.0	479	168	0.32	205	34	2.72

U = Analyte not detected at or above detection limit. Value presented is one half the detection limit.

J = Analyte detected above instrument detection limit, but below contract required detection limit.

NA = Not analyzed

TABLE 2-2
UNDISTURBED COLLUVIUM AND ANCESTRAL ALLUVIAL FAN DATA

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Colluvium - Undisturbed														
925	14.1		736		1,300		12.80		132		2,320		2.47	
929	16.6		665		823		0.96		53.8		810		1.54	
937	6.8		249		895		5.41		35.9		398		2.61	
930	7.6		790		1,400		3.99		54.5		1,290		0.44	
934	21.1		2,270		1,600		10.70		310		1,670		5.97	
935	17.3		953		10,900		38.90		755		3,540		6.48	
931	24.6		288		4,240		21.40		392		2,970		5.89	
933	8.6		246		1,240		6.18		34.9		940		1.39	
941	15.7		3,260		6,720		14.80		269		3,430		5.51	
942	13.2		424		1,340		20.40		106		4,730		2.96	
943	54.5		49500		2060		31.7		2540		7420		90.5	
944	23.0		737		1,240		1.72		67.2		2,310		3.06	
945	26.4		1,570		1,570		7.51		352		1,640		4.81	
946	24.7		2,290		1,500		10.90		273		2,760		5.73	
BK05	8.0		617		1,100		10.90		68		1,000	J	3.00	
BK13	22.0		228	J	1,180		4.20		26		555	J	1.00	
BK14	37.0		1,310	J	1,270		6.70		210		1,130	J	4.00	
RS05	10.0	U	280		1,400		6.00		33		880		5.00	U
Patrick	10.0		9,300		NA		2.10		NA		970		NA	
RS17	10.0	U	540		740		7.00		66		750		5.00	U
Ancestral Silver Creek Alluvial Fan Deposits - Undisturbed														
938	17.3		598		1,370		6.70		134		1,190		2.36	
939	17.3		554		2,230		5.12		131		746		5.12	
RSS05	37		1,080		1,830		9.0		224		1,430	J	9.0	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limt.

J = Analyte detected above instrument detection limit, but below contract required detection limit.

NA = Not analyzed

TABLE 2-3
DISTURBED COLLUVIUM AND ALLUVIAL FAN DATA

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Colluvium - Disturbed														
926	27.9		1,630		1,410		4.2		117		1,920		2.8	
932	18.5		1,150		1,430		11.5		119		1,830		5.2	
936	54.1		1,920		3,190		18.1		221		2,660		11.6	
940	19.5		1,390		1,700		13.8		165		2,030		6.8	
RSS30	29		3,920		3,450		34.3		263		4,820	J	16.0	
RSS31	18		893		1,260		5.5		154		932	J	3.0	
RSS23	25		851		1,000		8.5		114		1,240		5.0	
RSS24	29		2,100		2,710		22.0		234		3,560		12.0	
RSS07	28		2,230		1,840		27.9		152		3,060	J	14.0	
Ancestral Silver Creek Alluvial Fan Deposit - Disturbed														
RS24	30		1,000		1,900		11.0		190		1,700		5.0	U
RSS27	28		677		1,780		9.5		154		1,370		6.0	
RSS36	28		825		1,530		5.0		99		916	J	10.0	
RSS20	27		791	J	1,460		12.8		103		1,990	J	7.0	
School lots	5	U	650		NA		6.6		NA		1,500		NA	
RS04	26		160		1,500		10.0		170		1,500		10.0	
RS02	62		1,500		1,100		7.0		190		990		11.0	
RS18	10	U	1,400		2,400		13.0		110		2,400		5.0	U
Lots 17-20	5	U	830		NA		9.5		NA		2,000		NA	
RS16	10	U	750		1,800		6.0		84		1,300		5.0	U
RSS18	32		364	J	6,240		8.5		73		1,180	J	3.0	
RSS17	28		1,150	J	1,230		10.0		102		1,410	J	7.0	
RSS37	20		908		1,660		9.1		117		1,340	J	7.0	
RSS26	19		675		564		10.3		96		2,430		3.0	
RSS25	28		1,000		1,980		6.7		118		1,285		10.0	
RSS28	19		402		1,130		6.8		70		1,240	J	2.0	
Trench 2	10	U	230		NA		1.0	U	NA		410		NA	
Silver Creek Alluvial Fan Deposit - Disturbed														
RS21	10	U	3,400		2,900		38.0		240		5,300		18.0	
RS22	10	U	2,000		1,500		33.0		200		4,400		5.0	U
RS23	29		800		2,500		11.0		160		2,000		5.0	U
Iron Draw Alluvial Fan Deposit - Disturbed														
RSS10	36		143	J	1,030		1.5		66		200	J	1.0	
RSS22	39		380		1,970		1.9		88		369		1.0	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limit.

J = Analyte detected above instrument detection limit but below contract required detection limit.

NA = Not analyzed

TABLE 2-4
TALUS AND SLOPE WASH EAST DATA

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Talus/Slope Wash (East) - Undisturbed														
927	13.9		67		1,080		0.33		27		109		0.44	
928	24		210		833		0.32		111		412		1.37	
BK11w	5	U	62		NA		0.50	U	NA		150		NA	
BK10w	43		108	J	3,430		1.10		24		398	J	1.0	
BK38w	5	U	84		NA		0.50	U	NA		160		NA	
BK39w	14		96		NA		0.50	U	NA		160		NA	
BK01	16		206		604		0.50	U	23		252	J	1.0	U
BK02	18		412		552		3.10		97		515	J	2.0	
BK15	25		155		11,300		3.80		37		1,360	J	2.0	
BK03	25		82		818		4.30		33		506	J	1.0	
RSS34	16		306		851		6.90		103		919	J	2.0	
RSS02	51		112		1,360		0.30	U	40		174	J	1.0	
RSS03	23		105		923		0.90		28		169	J	1.0	
RSS04	34		138		3,220		25.40		159		1,880	J	3.0	
Group Tract	13		260		NA		2.10		NA		500		NA	
Ada North	9.8		77		NA		1.00	U	NA		120		NA	
RS01	10	U	100		1,100		1.00	U	27		190		5.0	U
Talus/Slope Wash (East) - Disturbed														
RSS06	17		240		634		4.80		58		717	J	2	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limit.

J = Analyte detected above instrument detection limit but below contract required detection limit.

NA = Not analyzed

TABLE 2-5
TALUS AND SLOPE WASH WEST DATA

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Talus/Slope Wash (West) - Undisturbed														
RSS09	28		184	J	1130		4.1		40		647	J	0.5	U
RSS12	27		124	J	710		1.0		125		175	J	0.5	U
RSS13	21		78	J	1090		0.80		49		171	J	0.5	U
BK07	19		66		1020		1.3		53		161	J	1.0	
BK08	24		57		872		0.35	U	39		98	J	0.5	U
BK09	20		141		2120		3.3		42		633	J	1.0	
BK10	43		108	J	3430		1.1		24		398	J	1.0	
BK11	38		64	J	1500		0.35	U	45		167	J	0.5	U
BK12	23		441	J	1250		6.3		184		685	J	1.0	
Talus/Slope Wash (West) - Disturbed														
RSS14	25		115	J	777		1.90		51		285	J	1	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limit.

J = Analyte detected above instrument detection limit but below contract required detection limit.

Sample RSS14 (Disturbed) was not included for statistical calculations.

TABLE 2-6
DOLORES RIVER CORRIDOR DATA

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Dolores River Corridor														
RSS15	32		424	J	2,560		5.7		84		927	J	26	
RSS16	25		471	J	894		6.7		93		860	J	3	
RS12	37		5,200		1,300		19.0		330		2,400		13	
RS19	28		12,000		800		23.0		260		3,700		21	
RS20	22		2,000		1,800		17.0		330		2,400		5	U
RS27	25		500		12,000		14.0		150		1,500		48	
RS25	40		1,200		1,200		4.0		200		1,100		12	
RS26	27		1,600		13,000		9.0		310		4,000		41	
RS28	10	U	3,500		2,000		17.0		420		2,600		14	
RSS19	98		6,180	J	529		9.2		641		1,520	J	34	
RSS11	56		124		1,900		1.2		94		226	J	2	
RSS35	16		146		1,020		2.6		46		360	J	0.5	U
RSS01	35		346		944		1.8		76		249	J	3	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limt.

J = Analyte detected above instrument detection limit, but below contract required detection limit.

TABLE 2-7
ROADFILL DATA

SAMPLE NUMBER	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
RSS21	31	1,760	1,650	23.7	221	2,860	12
RSS29	35	2,430	2,390	49.0	221	6,100	11
RSS33	25	368	1,210	6.2	87	1,100	2
Smuggler	12	420	NA	2.2	NA	460	NA
Hillside #2	24	9,100	NA	16.0	NA	2,400	NA
Hillside	26	2,800	NA	23.0	NA	3,400	NA
Home	21	300	NA	4.6	NA	780	NA
96-CH-02	4	2,260	2,470	37.8	264	5,080	15.6
96-CH-04	32	2,300	2,490	46.9	243	5,580	10.2

TABLE 2-8
WASTE ROCK DATA

SAMPLE NUMBER	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
RSS32 (Van Winkle)	24	7,960	5,410	119	494	18,200	27
Sam Patch	26	12,000	NA	17	NA	2,900	NA
RP-01 (Laura)	74	8,500	1,200	60	590	9,000	220
RP-03 (Atlantic Cable)	26	7,000	5,000	84	570	13,000	68
96-CH-03	8	18,600	8,770	276	1,360	37,900	52

TABLE 2-9
GRAND VIEW SMELTER DATA

SAMPLE NUMBER	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
RSS08	56	3,460	2,690	16.7	724	2,120 J	47
RS13	47	4,800	5,600	20	660	4,000	64
96-CH-01	22	6,290	8,180	13.8	796	6,040	42.5

J = Analyte detected above instrument detection limit but below contract required detection limit.

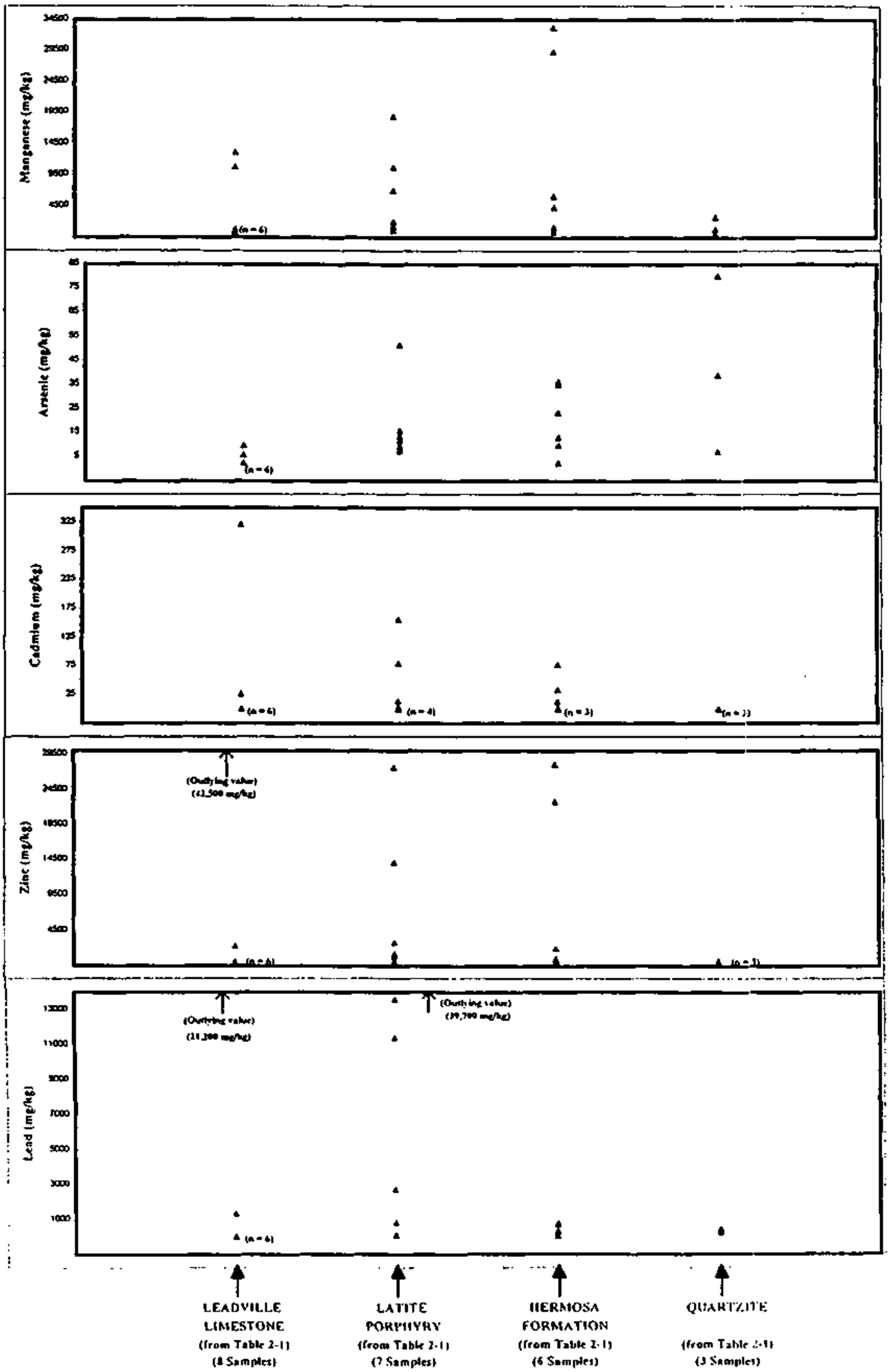
NA = Not Analyzed

TABLE 2-10
AVERAGE ABUNDANCES OF SELECTED MINERALS IN VARIOUS ROCK AND SOIL TYPES
(from Levinson, A.A., 1974 ; Parker, R.L., 1967)
(All values in ppm unless otherwise noted.)

	Granodiorite (L)	Intermediate Rocks (P)	Shale (L)	Sandstone (P)	Limestone (L)	Soil (L)
As	2	2.4	15	1	2.5	1-50
Cd	0.2	NR	0.2	0.01 - 0.09	0.1	1
Cu	30	35	50	16	15	2-100
Mn	1200	0.12 (wt%)	850	0.001 - 0.009 (wt%)	1100	850
Pb	15	15	20	7	8	NR
Zn	NR	72	NR	12	NR	NR

(L) from Levinson, A.A., 1974.
(P) from Parker, R.L., 1967.
NR = Not Reported

FIGURE 2-25
Range of Mn, As, Cd, Zn, and Pb Contents in Samples of Four Principal Bedrock Outcrop Units Northeast Rico, Colorado



The seven bedrock samples of latite porphyry have a wide range of metal contents but all are significantly metallized; arsenic ranges from 7.6 to 51.7 ppm (mean of 17 ppm), lead from 84 to 39,700 ppm (mean of 9,765 ppm), manganese from 652 to 18,800 ppm (mean of 6,000 ppm), cadmium from 0.31 to 157 ppm (mean of 37 ppm), and zinc from 162 to 27,700 ppm (mean of 6,750 ppm). Even the two most weakly metallized latite porphyry samples (samples 918 and 919, Table 2-1), have arsenic, lead, cadmium, zinc, and especially copper and silver contents that are three or more times that in intermediate volcanic rocks in general (Table 2-10). The overall metallized nature of the latite porphyry probably reflects the highly fractured character of this bedrock unit (Figure 2-15) as these fractures facilitated migration of hydrothermal fluids through the host bedrock.

Samples of the Hermosa Formation are also highly metallized. The six samples (Table 2-1) show a wide range of metal contents (as in the latite porphyry) but they contain the highest mean arsenic (mean of 20.1 ppm) and manganese (mean of 12,450 ppm) of all the bedrock units. In general, these samples are all anomalous in base metals compared to abundances commonly found in shales and sandstones (Table 2-10). One sample in this group (sample 914, Table 2-1) has the distinction of being the least metal-rich of all the bedrock samples but even it has a copper content (231 ppm) four times that of common shales (50 ppm, Table 2-10).

The three samples of quartzite (Table 2-1) are weakly metallized in comparison to latite porphyry and Hermosa Formation samples but they do have significantly elevated arsenic (sample 915 contains the highest arsenic of all the bedrock samples, 80.2 ppm) and anomalous lead (242 to 479 ppm) contents.

In summary, the 24 bedrock samples, from outcrops scattered across the north part of Rico, are all weakly to strongly metallized. Their mean metal contents as a group are 16.5 ppm arsenic, almost 4,000 ppm lead, 6,120 ppm manganese, 30.8 ppm cadmium, and 6,150 ppm zinc. This metallization is further evidence of the pervasive impact of the large hydrothermal system developed in the area 3.5 to 5 Ma (Larson and others, 1994a; 1994b). As these rocks are exposed at and near the surface, they are the principal source of rocks and minerals in the native, colluvial soils that are characteristic of the north part of Rico. These colluvial soils also have elevated metal contents as would be expected of materials that closely reflect the character of the underlying bedrock.

2.6.2 Colluvium

The samples of native colluvium include 20 that are of undisturbed materials (Table 2-2) and 9 of disturbed materials (Table 2-3). The analytical data for these samples are summarized in Figure 2-26 and the sample locations are shown in Figure 2-19. The colluvium sample data in general shows elevated metal contents. The native, undisturbed colluvium (excluding sample 943, Table 2-2) contains 6.8 to 37 ppm arsenic (mean of 16.7 ppm), 228 to 9,300 ppm lead (mean of 1,400 ppm), 740 to 10,900 ppm manganese (mean of 2,250 ppm), 0.96 to 38.9 ppm cadmium (mean of 10.1 ppm), and 398 to 4,730 ppm zinc (mean of 1,790 ppm). These broad ranges are similar to those for bedrock samples but the variances are much less (Tables 2-1, 2-2, and 2-3). This is to be expected as the development of colluvium mixes and begins to homogenize the weathered bedrock material. Note that one undisturbed colluvium sample contains the highest lead content of all the bedrock and surficial samples. This is sample 943 in Table 2-2 which contains almost 5 % lead. This composite chip sample was collected from the section of colluvium exposed in the excavation shown in Figure 2-14. Although clearly native colluvium, data for this sample have not been included in the statistical characterization of the dataset, including the ranges mentioned above.

The data for disturbed colluvium are listed in Table 2-3 and shown in Figure 2-21. The metal content of this graded, excavated, raked or otherwise surface modified-material clearly overlaps that of the undisturbed colluvium but the mean values are slightly higher for arsenic (28 ppm), lead (1,790 ppm), cadmium (16.2 ppm), and zinc (2,450 ppm) and the ranges are narrower. This may reflect a concentration of fine-grained material in the upper few inches of surface material compared to the rock-rich undisturbed colluvium as in Figure 2-14.

The geochemistry of soils is highly variable and, unlike rocks, soils are more area-specific in their basic characteristics but a comparison to some compiled soil chemistry data (Table 2-10) shows that cadmium, lead, manganese, and zinc have high concentrations in Rico colluvium. This is not a surprise as these materials are formed from the weathering of the underlying metallized bedrock (see above).

2.6.3 Talus and Slope Wash

The metal content of talus and slope wash is listed in Table 2-4 for samples from the east slopes of town and in Table 2-5 for those from the west. These data are also summarized in Figure 2-27 and the location of all the samples is shown in Figure 2-19. Only two of the combined 26 samples are from disturbed areas and the datasets primarily represent the undisturbed natural mantle of weathered rock debris that is mixed as it is slowly transported downslope. These materials are derived from higher elevations on the mountains surrounding Rico where some of the bedrock is farther removed from the center of the Rico hydrothermal system than the bedrock within town. The analytical data show that the sources of the talus and slope wash, as a whole, are much less metallized than the surficial materials derived locally in town. On the eastern

FIGURE 2-26
Range of Mn, As, Cd, Zn, and Pb Contents
in Samples from Disturbed and Undisturbed Colluvium
Northeast Rico, Colorado

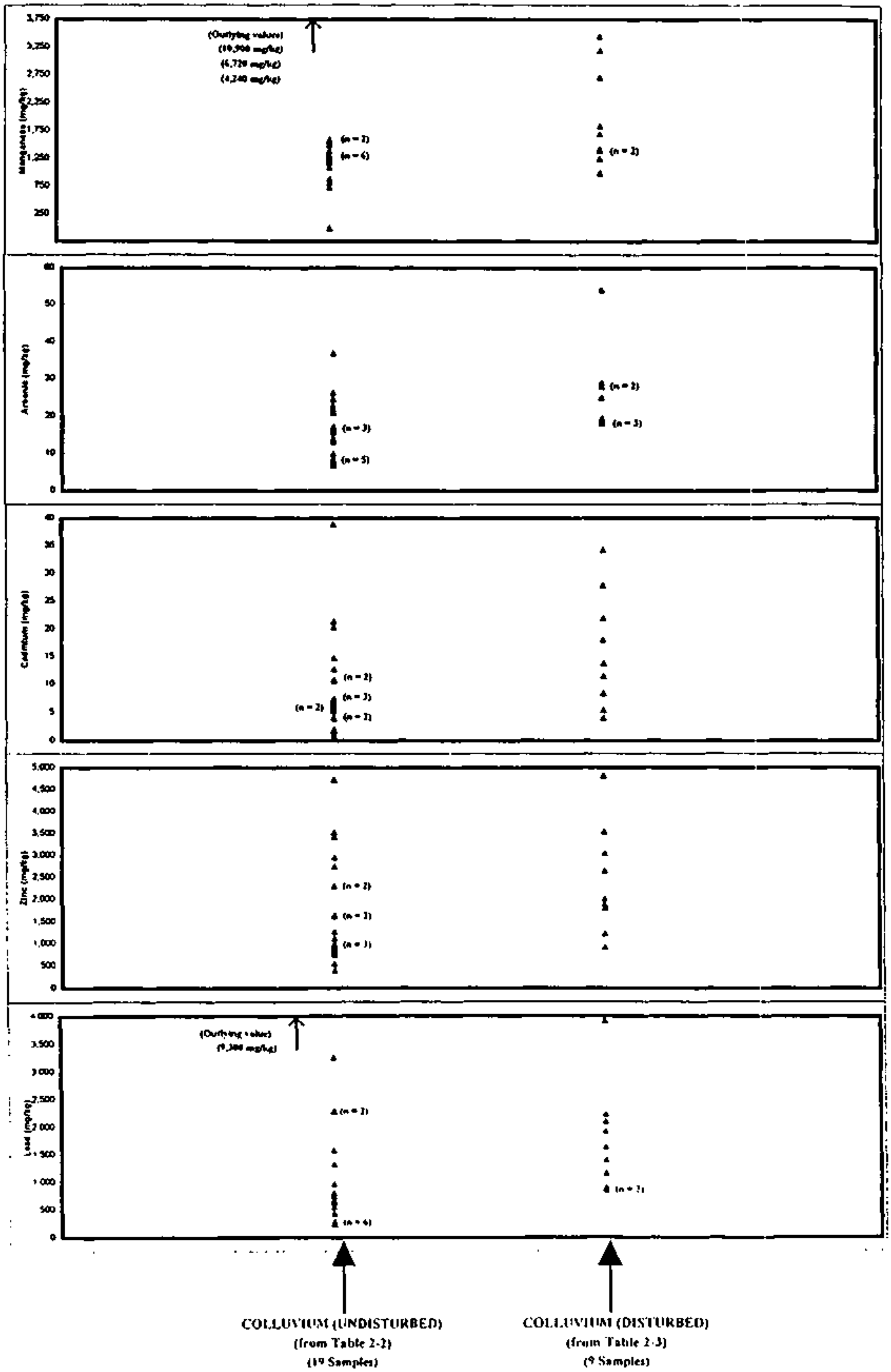
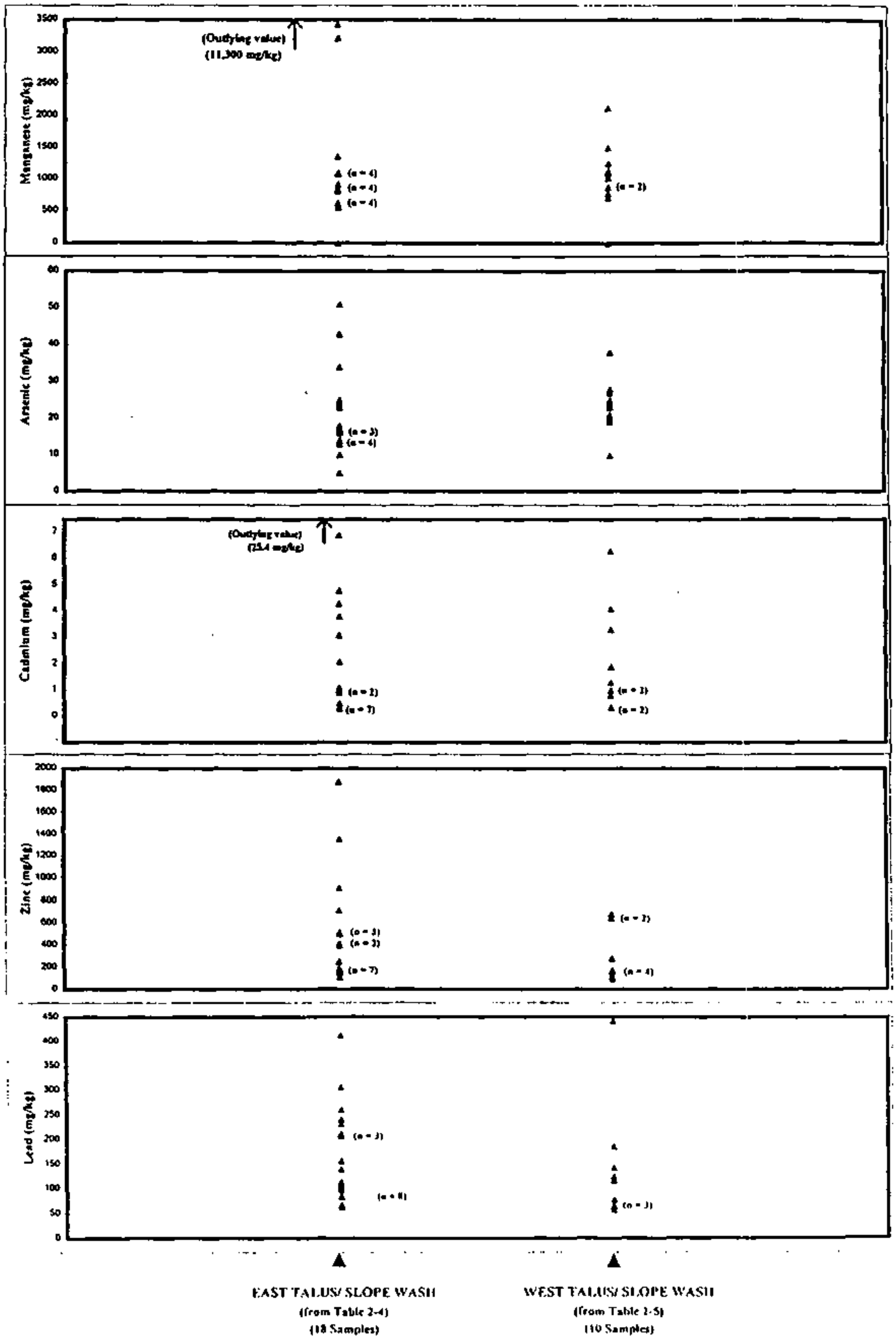


FIGURE 2-27
Range of Mn, As, Cd, Zn, and Pb Contents
in Samples of Talus/ Slope Wash from the East and West Slopes
Rico, Colorado



Metals.xls/ 3/29/96

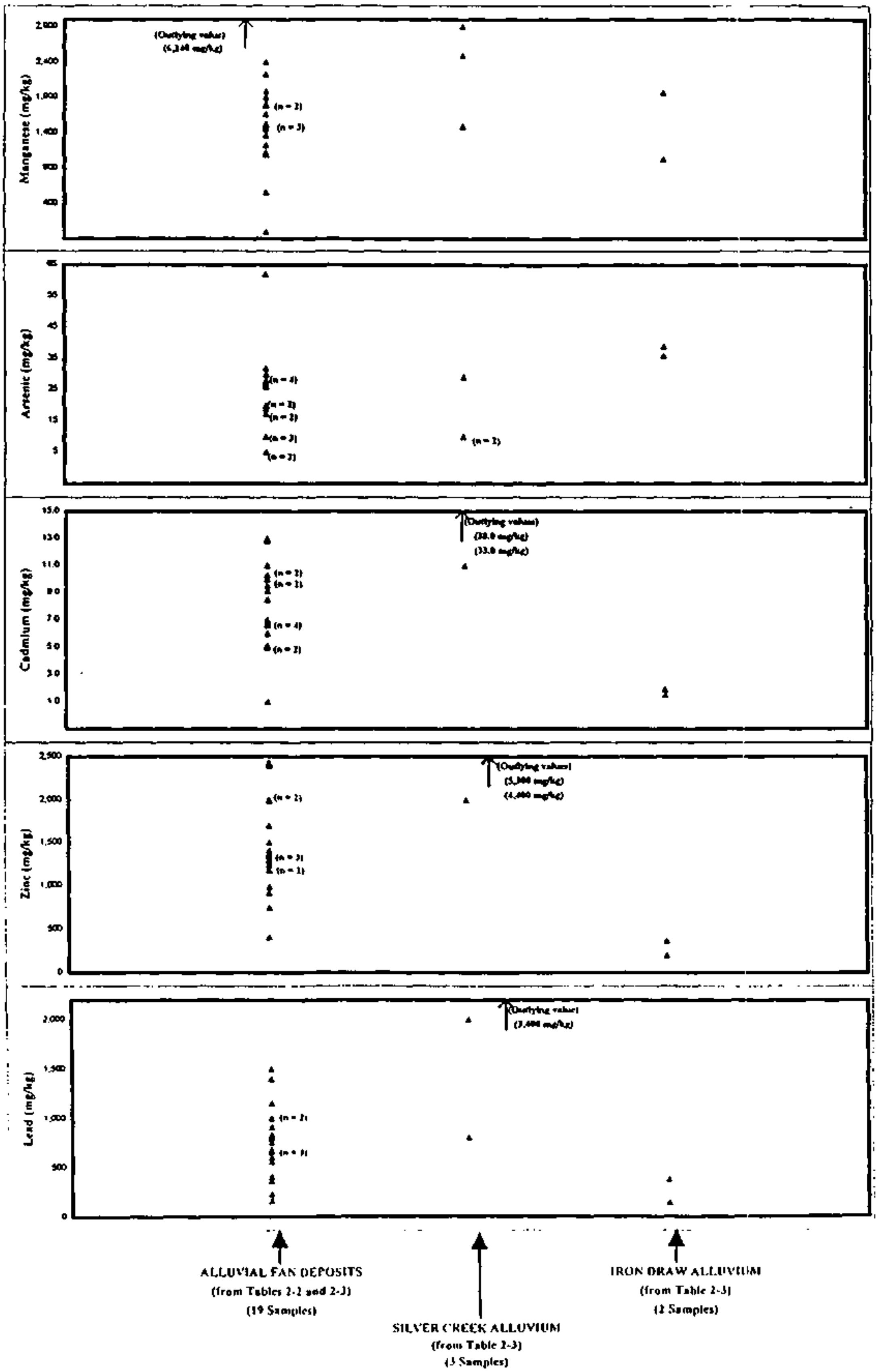
slopes, arsenic ranges from 5 to 51 ppm (mean of 20.4 ppm), lead from 62 to 412 ppm (mean of 152 ppm), manganese from 552 to 11,300 ppm (mean of 2,170 ppm), cadmium from 0.3 to 25.4 ppm (mean of 3.1 ppm), and zinc from 109 to 1,880 ppm (mean of 470 ppm). On the western slopes, arsenic ranges from 19 to 43 ppm (mean of 27 ppm), lead from 57 to 441 ppm (mean of 140 ppm), manganese from 710 to 3,430 ppm (mean of 1,460 ppm), cadmium from 0.35 to 6.3 ppm (mean of 2.1 ppm), and zinc from 98 to 685 ppm (mean of 354 ppm). Figure 2-27 shows that the ranges of these metals in east and west slope soils clearly overlap each other but there are some indications, such as the locally high manganese, cadmium, and zinc contents, that the east slope samples have metallized source areas upslope (the Newman Hill mining area is in the upslope source area of this material). In general, these east and west talus and slope wash materials have the lowest metal contents of the surficial units in the Rico area and, although their mean metal contents are several times that in many common sedimentary rocks, they are in the range of some common soils elsewhere (Table 2-10).

2.6.4 Alluvial Fans

There are sample data for all three alluvial fans in the Town of Rico; the ancestral Silver Creek alluvial fan, the active Silver Creek alluvial fan, and Iron Draw alluvial fan in west Rico. These data are listed in Tables 2-2 and 2-3 and shown diagrammatically in Figure 2-28.

The ancestral Silver Creek alluvial fan makes up the surface materials upon which most of south Rico is developed. These poorly sorted gravels have, at the surface, almost all been disturbed to one degree or another by the dominantly residential-related development activities (road construction, excavation, housing construction, yard improvements, etc.). Most of the samples therefore represent disturbed materials although three samples of undisturbed ancestral Silver Creek alluvial fan are also available (Table 2-2). The disturbed ancestral alluvium (Table 2-3) has arsenic ranges from 5 to 62 ppm (mean of 22.8 ppm), lead from 230 to 1,500 ppm (mean of 724 ppm), manganese from 562 to 6,240 ppm (mean of 1,755 ppm), cadmium from 1 to 13 ppm (mean of 8.4 ppm), and zinc from 410 to 2,430 ppm (mean of 1,470 ppm). The three samples of undisturbed ancestral Silver Creek alluvium (Table 2-2) have metal contents that are very similar to those in the disturbed ancestral alluvium thus indicating that residential development has not drastically changed the original metal content of these materials. The mean metal contents, with the exception of arsenic, are two to several times that common in rocks and soils elsewhere (Table 2-10) but, compared to the colluvium of north Rico (above), the ancestral alluvial fan materials in south Rico are lower in metal content. In general, the ancestral alluvial gravels have moderately elevated metal contents that reflect the mineralized character of the source areas upstream on Silver Creek. This upstream source area, the principal base metal mining area of the district, includes the highly mineralized Blackhawk fault zone that transects the Silver Creek

FIGURE 2-28
Range of Mn, As, Cd, Zn, and Pb Contents in Samples from Alluvial Fan Deposits
Rico, Colorado



Metals.xls/ 3/29/96

drainage just 1.2 miles upstream from Rico. In effect, the ancestral Silver Creek gravels have incorporated enough mineralized material to clearly indicate the presence of the upstream mineralized areas.

The active Silver Creek alluvial fan is a relatively small area of reworked ancestral Silver Creek alluvium and recently deposited coarse bouldery-gravel that is being carried by the active stream where it enters onto the Dolores River floodplain (Figure 2-5). Characterizing this area is further complicated by the outcropping of ore deposits in the channel of Silver Creek at the head of this alluvial fan and the local disturbances from mining activity (trenching, mine wasterock dumps, etc.) associated with the Atlantic Cable mine (above). The three samples of active Silver Creek alluvial materials have mean metal contents of 16.3 ppm arsenic, 2,070 ppm lead, 2,300 ppm manganese, 27.3 ppm cadmium, and 3,900 ppm zinc. To what degree this reflects the natural character of the materials or the mixing in of higher grade mine wasterock is not clear.

The Iron Draw alluvial fan is deposited at the mouth of Iron Draw where it enters onto the floodplain of the Dolores River. Iron Draw is a relatively small drainage with a limited source area to derive the alluvial materials. The alluvial materials are poorly sorted and reworked talus and slope wash from the west slopes of the Rico area (above). The analytical data (two samples of disturbed alluvium, Table 2-3), indicate relatively low metal contents like that for the western talus and slope wash (Table 2-5) as would be expected.

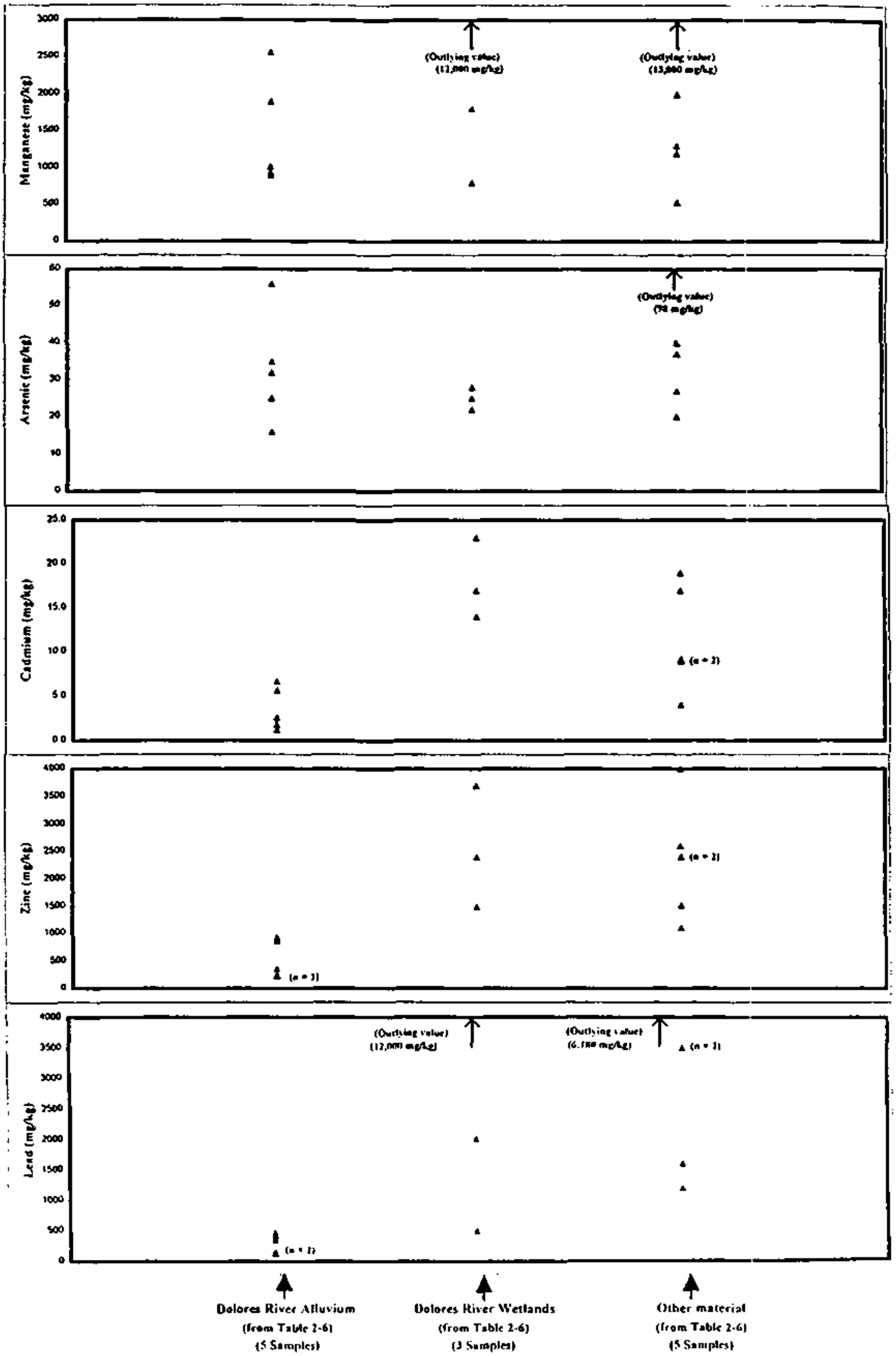
2.6.5 River Corridor

A total of 13 samples are available to characterize the distribution of metals in various materials of the Dolores River Corridor (Table 2-6). The surface and near surface materials are dominantly silt, sand, and gravel of the Dolores River floodplain but the corridor contains a wide range of materials with complicated origins ranging from undisturbed natural wetlands to highly disturbed materials, some exotic to the natural river corridor such as coal and cinders, that are associated with the once extensive facilities of the Rio Grande Southern Railroad. Because of this complexity, the individual sample descriptions are compiled here in Table 2-11 and data for three categories of samples are shown in Figure 2-29. In general, the sample data confirm the mix of origins and materials in the corridor as there is a highly variable and wide range of metal. What is unique to the river corridor dataset are samples from wetlands (RS 19, RS 20, and RS 27, Table 2-11). The highest lead content of all the river corridor samples is 12,000 ppm from a wetland upstream of the mouth of Silver Creek (sample RS 19, Table 2-11, Figure 2-24), and the highest manganese content, 12,000 ppm, is also from a wetland (sample RS 27, Table 2-11, Figure 2-24). These data suggest that metals in surface and near surface waters of the Dolores River, although low in concentration overall (see discussion of Dolores River water quality in the Columbia

TABLE 2-11
DESCRIPTIONS OF SAMPLES FOR THE DOLORES RIVER CORRIDOR

SAMPLE NUMBER	DESCRIPTION
RS-12	RS-12 was a four-point composite collected from Block 12, within lots 31 and 36 and Block 25, within lots 5 and 11. Blocks 12 and 25 are located on the west side of Rico in the floodplain of the Dolores River. The sample was from 0 to 2 inches depth and consisted of alluvium mixed with mine waste rock.
RS-15	RS-15 was a three-point composite from 0 to 6 inches depth from Block 21, lot 1. The sample consisted of fill material mixed with native soil. The fill material contained some mineralized mine waste.
RS-16	RS-16 was collected from Block 2, lot 9-12. The sample was a three-point composite from 0 to 8 inches depth. The sample consisted of both fill material and possibly some native soil.
RS-19	RS-19 was a four-point composite from 0 to 2 inches depth. It was collected from wetlands along the east side of the Dolores River and west of Block 28.
RS-20	RS-20 was collected from wetlands along the east side of the Dolores River and west of Block 27. The sample was a four-point composite from 0 to 2 inches depth and consisted of native soil.
RS-25	RS-25 was collected from the former train depot site. The sample consisted of clinkers and fill material mixed with alluvium. The sample was a four-point composite form 0 to 2 inches.
RS-26	RS-26 was collected in dump debris along the Dolores River. The sample was a three-point composite from 0 to 6 inches depth.
RS-27	RS-27 was collected from wetlands along the east side of the A.E. Arms Tract. The sample consisted of native soil and was a four-point composite from 0 to 2 inches depth.
RS-28	RS-28 was collected from Block 25, lots 1-4. This sample consisted of disturbed alluvium and possibly some mine waste. It was a four-point composite form 0 to 2 inches in depth.
RSS-01	RSS-01 was collected from a grass covered river terrace. This sample consisted of alluvium with coarse fragments of sandstone and shale. No mineralization was observed. A small sulfide waste pile is located 25 feet south of the sample location.
RSS-11	RSS-11 was collected from grassy, cobbly alluvium near the edge of the floodplain.
RSS-19	RSS-19 consisted of Dolores River alluvium. Pyrite, alteration, and mineralization were not observed.
RSS-35	RSS-35 consisted of sandy loam on the Dolores River floodplain, between the wetland areas.

FIGURE 2-29
Range of Mn, As, Cd, Zn, and Pb Contents
in Samples from the Dolores River Corridor
Rico, Colorado



tailings VCUP application), are being scavenged to a degree by natural wetlands in the river system.

2.6.6 Other Materials

Other materials for which sample data exist are anthropogenic in their origins. These include roadfill, mine wasterock, and smelter wastes (Tables 2-7, 2-8, and 2-9). Only the main street, Glasgow Avenue, is paved and some of the nine samples of roadfill material have metal contents that reflect the use of mine wasterock for this purpose over the years (S. Foster, verbal communication, 1996). For example, the lead content of these samples, ranging from 300 to 9,100 ppm (mean of 2,415 ppm) indicates mixed sources and an overall character that is not a lot different from natural bedrock or colluvium in the area (see above).

The data for mine wasterock complements that compiled for the Silver Swan mine VCUP application and, although from several different wasterock dumps, basically confirms that elevated contents of lead (to 18,600 ppm or 1.8 %), manganese (to 8,770 ppm), cadmium (to 276 ppm), and zinc (to 37,900 ppm or 3.8 %) are present in these materials. Interestingly, the arsenic content of these materials (mean of 32 ppm) is not especially elevated compared to other surficial materials of the Rico area. This is because arsenic is not correlated with base metals in the Rico area as a whole (see below).

Smelter wastes: **The three samples of smelter waste materials (Table 2-9) are all from the Grand View smelter area. These samples have mean metal contents of 42 ppm arsenic, 4,850 ppm lead, 5,490 ppm manganese, 16.8 ppm cadmium, and 4,050 ppm zinc. These are elevated metal contents and although similar to that in some other surficial materials, natural and otherwise, in the Rico area (see above), these metals are present in a complex assemblage of minerals, cinders, and glass (slag). This processed character is a significant difference between the smelter wastes here and all other materials discussed above; conclusions based on comparisons of metal content between them should not be made.**

2.6.7 Summary and Discussion

The distribution and amounts of metals in the bedrock and surficial materials in the Town of Rico everywhere shows the influence of the extensive hydrothermal system that developed 3.5 to 5 Ma ago. The bedrock in the town has the highest overall metal contents and the colluvium derived from this bedrock has levels almost as high. Even the more mobile, transported and homogenized surficial materials such as ancestral Silver Creek alluvium is anomalous in it's metal content and reflective of the highly metallized character of bedrock in the Silver Creek drainage near Rico. Even the least metal-rich surficial materials, the talus and slope wash on the steeper slopes on the east and west sides of town, have some indications of being nearby to a major hydrothermal system.

The principal sources of metals are natural. These sources have been shown to be exposed and near surface bedrock and the materials derived in various ways from this bedrock. The detailed mineralogy of these materials confirms the linkages defined by the map and sample data. The town is very dominantly developed on these natural materials and the mining-related impacts, such as wasterock dumps, are discrete and individually definable. The development of the town has impacted a large part of the original, natural surfaces. Comparisons of disturbed and undisturbed datasets for colluvium and ancestral Silver Creek alluvium indicate that town development has not significantly changed the original natural metal distribution where these materials are present. Road development has locally increased surface metal contents through the use of mine wasterock for fill and erosion, flooding, and development in the area of the active Silver Creek alluvial fan has resulted in what appears to be a complicated mix of origins and metal contents in the surface materials of this area.

Because of the well-developed spatial characterization of the surficial materials, it is possible to identify the samples that represent the original and natural metal sources within the town. These samples in turn define the background values for metals in the specific areas the samples represent. Such backgrounds can be defined for the area dominated by bedrock and colluvium (north Rico), the ancestral Silver Creek fan (south Rico), and the steeper slopes on both the east and west sides of town.

The background metal values for north Rico can be defined by merging the bedrock and undisturbed colluvium data (Tables 2-1 and 2-2). This can be done by estimating the aerial proportion of exposed and very near-surface bedrock (approximately 5 percent, see Figure 2-18) and developing an aerially weighted average with the undisturbed colluvium data. This calculation defines mean background values of 16.7 ppm arsenic, 1,535 ppm lead, 2,440 ppm manganese, 11.2 ppm cadmium, and 2,010 ppm zinc for the north Rico area (Table 2-12).

The area of the ancestral Silver Creek alluvial fan, south Rico, has three samples that are representative of undisturbed, original materials. These samples define mean background levels of 23.9 ppm arsenic, 744 ppm lead, 1,830 ppm manganese, 6.9 ppm cadmium, and 1,120 ppm zinc (Table 2-13). Although this is not a large dataset, the mean values are very similar to those for the disturbed ancestral alluvium in same south Rico area (Table 2-13).

TABLE 2-12
NORTH RICO BACKGROUND DATA
MEAN METAL CONCENTRATIONS
RICO, COLORADO

	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
MEAN (BEDROCK) (from Table 2-1)	16	3,940	6,120	31	371	6,150	12
MEAN (COLLUVIUM) (from Table 2-2)	17	1,410	2,250	10	180	1,790	3.7
MEAN BACKGROUND FOR NORTH RICO [1]	17	1,540	2,440	11	189	2,010	4.1

(1) Background statistics for North Rico are areally-weighted averages of bedrock outcrop data and undisturbed colluvium data (the average assumes that the ground surface is composed of 5% bedrock outcrop and 95% colluvium).

TABLE 2-13
SOUTH RICO BACKGROUND DATA
ANCESTRAL SILVER CREEK ALLUVIAL FAN DEPOSITS - UNDISTURBED
RICO, COLORADO

	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Alluvial Fan Deposits - Undisturbed														
938	17		598		1,370		6.7		134		1,190		2.4	
939	17		554		2,230		5.1		131		746		5.1	
RSS05	37		1,080		1,830		9.0		224		1,430	J	9.0	
MEAN BACKGROUND FOR SOUTH RICO	**24**		**744**		**1810**		**6.9**		**163**		**1120**		**5.5**	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limt.

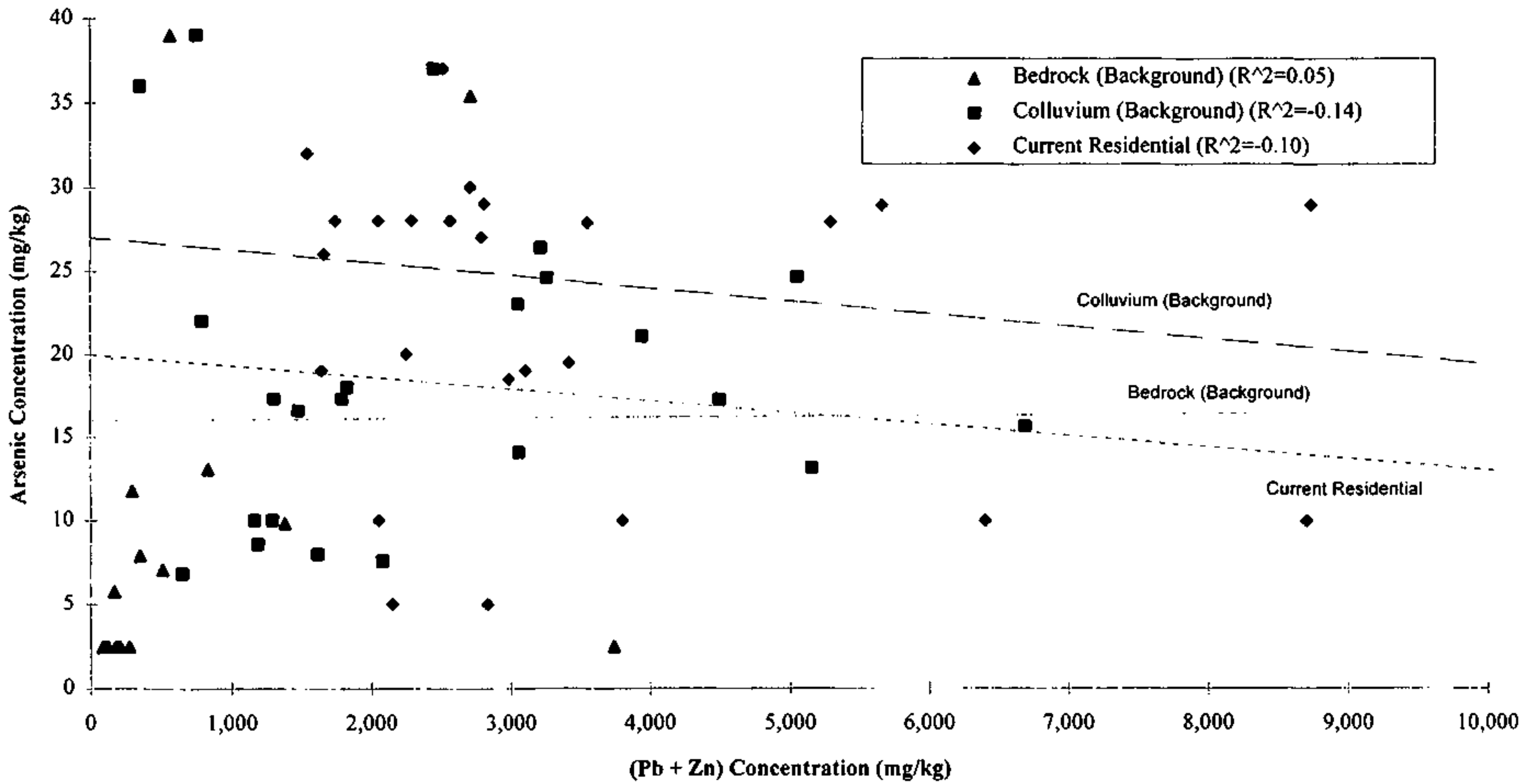
J = Analyte detected above instrument detection limit, but below contract required detection limit.

NA = Not analyzed

The datasets for the east and west slopes of Rico are very dominantly samples representative of undisturbed talus and slope wash. The mean metal values for these datasets are therefore the mean background metal values for these areas. These mean background values are listed in Tables 2-4 and 2-5.

Arsenic is widely distributed at low levels through the Rico area and Figure 2-30 shows that this metal is not anywhere correlated with base metals. This is consistent with the lack of arsenic minerals in the sulfide assemblages making up the ore deposits and mineralized areas of the district (McKnight, 1974). This relationship may indicate that (1) the hydrothermal system impacting the district as a whole had low levels of arsenic, and (2) the high mobility of arsenic (particularly at the hydrothermal stage, Levinson, 1980) led to it being more extensively dispersed compared to the base metals.

Figure 2-30
The Sum of Lead and Zinc Concentrations vs. Arsenic Concentrations



c:\rico\risk3.xls\As-Pb+Zn cht(2) [4/4/96]

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3.0 APPLICABLE STANDARDS/RISK DETERMINATION

"The applicant should provide a description of applicable promulgated state standards establishing acceptable concentrations of constituents (present at the site) in soils, surface water, or ground water."

"The applicant should provide a description of the human and environmental exposure to contamination at the site based on the property's current use and any future use proposed by the property owner."

Identification of applicable state standards is central to the assessment of metal exposures at Rico, as well as being a direct requirement of the VCUP application. When applicable state and federal standards do not exist for a media or parameter of concern, then it is necessary to establish acceptable levels based on a risk determination. The following sections identify state and federal criteria that may be appropriate for comparison to metals concentrations in soils at Rico, evaluates naturally occurring (background) sources of metals described above and presents the results of a health risk assessment (HRA) conducted according to EPA guidance for exposure to soils at Rico.

3.1 Data Consolidation

Figure 2-24 shows the generalized surficial geology of the Rico area that is described and discussed in detail above, and soil sample locations. Information presented on this map was combined with that on Figure 2-4 to assist with identification of exposure scenarios for the different sample locations. For example, the river corridor area has been identified as an area of potential open space in future land use plans (Figure 2-4). Therefore, recreational-type exposures to the metal values indicated by the sample data (Figure 2-24; Table 2-6) were deemed appropriate here. Similarly, parts of the east and west talus slopes of the town may be areas of future development; therefore, exposures in these areas are evaluated as residential. This process defined the six exposure areas shown on Figure 3-1.

The sample data originally compiled in Tables 2-1 through 2-9 are recompiled here in order to facilitate statistical calculations involving samples representative of metal concentrations in each exposure area (Figure 3-1); North Rico (Tables 3-1 and 3-2), South Rico (Tables 3-3 and 3-4), East Rico (Table 3-5), West Rico (Table 3-6), the Silver Creek Alluvial Fan (Table 3-7), and the River Corridor (Table 3-9). In addition, exposure scenarios and related risk assessments have been developed for two other types of surficial materials present locally in the Rico area; roadfill, and mine waste rock. Data for these areas are presented in Tables 3-10 and 3-11. Data obtained from smelter waste at the Grand View Smelter site was also used to evaluate health risks. Sample data and statistical calculations for this area are presented in Table 3-8. The determination

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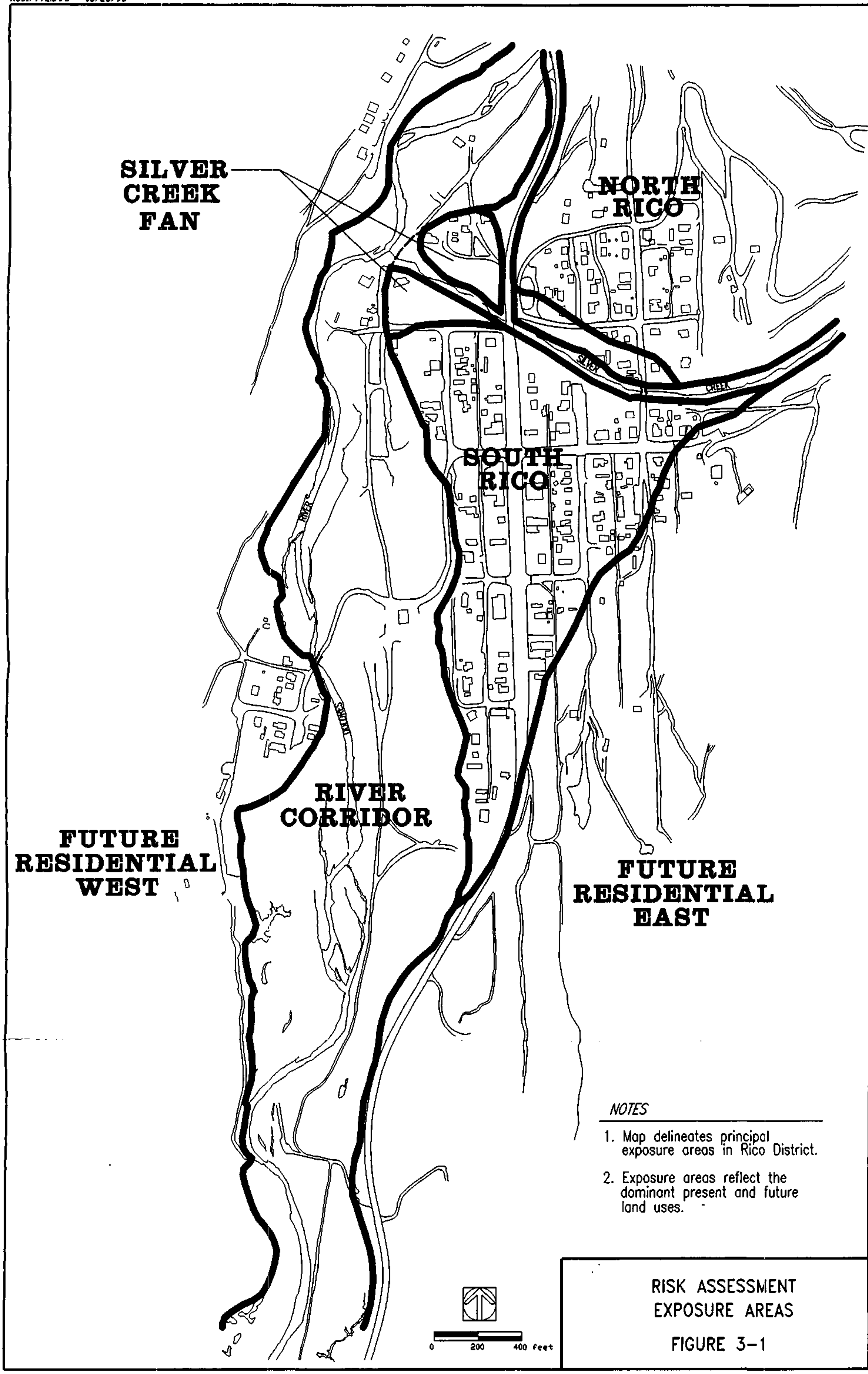


NOTES

1. Map delineates principal exposure areas in Rico District.
2. Exposure areas reflect the dominant present and future land uses.

RISK ASSESSMENT
EXPOSURE AREAS

FIGURE 3-1

TABLE 3-1
NORTH RICO RESIDENTIAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)		Ag (mg/Kg)
Colluvium - Disturbed								
926	27.9	1,630	1,410	4.2	117	1,920		2.8
932	18.5	1,150	1,430	11.5	119	1,830		5.2
936	54.1	1,920	3,190	18.1	221	2,660		11.6
940	19.5	1,390	1,700	13.8	165	2,030		6.8
RSS30	29	3,920	3,450	34.3	263	4,820	J	16.0
RSS31	18	893	1,260	5.5	154	932	J	3.0
RSS23	25	851	1,000	8.5	114	1,240		5.0
RSS24	29	2,100	2,710	22.0	234	3,560		12.0
RSS07	28	2,230	1,840	27.9	152	3,060	J	14.0
N	9	9	9	9	9	9		9
MIN	18	851	1000	4.2	114	932		2.8
MAX	54	3920	3450	34	263	4820		16
MEAN	28	1790	2000	16	171	2450		8.5
GEOMEAN	26	1600	1840	13	163	2190		7.1
MEDIAN	28	1630	1700	14	154	2030		6.8
STDEV	11	944	892	10	55.3	1220		5.0
VARIANCE	120	8.91E+05	7.95E+05	106	3061	1.48E+06		25
T-VALUE	1.86	1.86	1.86	1.86	1.86	1.86		1.86
95% UCL	34	2380	2550	23	205	3210		12
FREQUENCY	9/9	9/9	9/9	9/9	9/9	9/9		9/9

TABLE 3-2
NORTH RICO BACKGROUND DATA
MEAN AND 95% UCL METAL CONCENTRATIONS
RICO, COLORADO

	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
MEAN (BEDROCK) (from Table 2-1)	16	3,940	6,120	31	371	6,150	12
MEAN (COLLUVIUM) (from Table 2-2)	17	1,410	2,250	10	180	1,790	3.7
MEAN BACKGROUND FOR NORTH RICO (1)	17	1,540	2,440	11	189	2,010	4.1
95% UCL (BEDROCK) (from Table 2-1)	23	7,180	9,340	56	524	10,300	19
95% UCL (COLLUVIUM) (from Table 2-2)	20	2,240	3,310	14	257	2,280	4.5
95% UCL BACKGROUND FOR NORTH RICO (1)	20	2,490	3,610	16	271	2,680	5.2

(1) Background statistics for North Rico are areally-weighted averages of bedrock outcrop data and colluvium data (ie. assumes the area is approximately 5% bedrock outcrop and 95% colluvium).

TABLE 3-3
SOUTH RICO RESIDENTIAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Alluvial Fan Deposits - Disturbed														
RS24	30		1,000		1,900		11.0		190		1,700		5.0	U
RSS27	28		677		1,780		9.5		154		1,370		6.0	
RSS36	28		825		1,530		5.0		99		916	J	10.0	
RSS20	27		791	J	1,460		12.8		103		1,990	J	7.0	
School lots	5	U	650		NA		6.6		NA		1,500		NA	
RS04	26		160		1,500		10.0		170		1,500		10.0	
RS02	62		1,500		1,100		7.0		190		990		11.0	
RS18	10	U	1,400		2,400		13.0		110		2,400		5.0	U
Lots 17-20	5	U	830		NA		9.5		NA		2,000		NA	
RS16	10	U	750		1,800		6.0		84		1,300		5.0	U
RSS18	32		364	J	6,240		8.5		73		1,180	J	3.0	
RSS17	28		1,150	J	1,230		10.0		102		1,410	J	7.0	
RSS37	20		908		1,660		9.1		117		1,340	J	7.0	
RSS26	19		675		564		10.3		96		2,430		3.0	
RSS25	28		1,000		1,980		6.7		118		1,285		10.0	
RSS28	19		402		1,130		6.8		70		1,240	J	2.0	
Trench 2	10	U	230		NA		1.0	U	NA		410		NA	
N	17		17		14		17		14		17		14	
MIN	5.0		160		564		1.0		70.0		410		2.0	
MAX	62		1500		6240		13		190		2430		11	
MEAN	23		783		1880		8.4		120		1470		6.5	
GEOMEAN	19		680		1620		7.5		114		1370		5.8	
MEDIAN	26		791		1600		9.1		107		1370		6.5	
STDEV	14		371		1330		3.0		40.4		517		2.9	
VARIANCE	190		1.37E+05		1.78E+06		8.9		1631		2.68E+05		8.4	
T-VALUE	1.746		1.746		1.771		1.746		1.771		1.746		1.771	
95% UCL	29		940		2510		9.7		139		1690		7.9	
FREQUENCY	12/17		17/17		17/17		17/17		17/17		17/17		11/14	

TABLE 3-4
SOUTH RICO BACKGROUND DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
Alluvial Fan Deposits - Undisturbed							
938	17.3	598	1,370	6.7	134	1,190	2.4
939	17.3	554	2,230	5.1	131	746	5.1
RSS05	37.0	1,080	1,830	9.0	224	1,430 J	9.0
N	3	3	3	3	3	3	3
MIN	17	554	1370	5.1	131	746	2.4
MAX	37	1080	2230	9.0	224	1430	9.0
MEAN	24	744	1810	6.9	163	1120	5.5
GEOMEAN	22	710	1780	6.8	158	1080	4.8
MEDIAN	17	598	1830	6.7	134	1190	5.1
STDEV	11	292	430	2.0	52.8	347	3.3
VARIANCE	130	60	60	60	60	60	60
T-VALUE	2.92	2.92	2.92	2.92	2.92	2.92	2.92
95% UCL	43	1240	2540	10	252	1710	11
FREQUENCY	3/3	3/3	3/3	3/3	3/3	3/3	3/3

U = Analyte not detected at or above detection limit. Value presented is one half the detection limt.

J = Analyte detected above instrument detection limit, but below contract required detection limit.

NA = Not analyzed

TABLE 3-5
EAST RICO FUTURE RESIDENTIAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
927	13.9		67		1,080		0.33		27		109		0.44	
928	24		210		833		0.32		111		412		1.37	
BK11w	5	U	62		NA		0.50	U	NA		150		NA	
BK10w	43		108	J	3,430		1.10		24		398	J	1.0	
BK38w	5	U	84		NA		0.50	U	NA		160		NA	
BK39w	14		96		NA		0.50	U	NA		160		NA	
BK01	16		206		604		0.50	U	23		252	J	1.0	U
BK02	18		412		552		3.10		97		515	J	2.0	
BK15	25		155		11,300		3.80		37		1,360	J	2.0	
BK03	25		82		818		4.30		33		506	J	1.0	
RSS34	16		306		851		6.90		103		919	J	2.0	
RSS02	51		112		1,360		0.30	U	40		174	J	1.0	
RSS03	23		105		923		0.90		28		169	J	1.0	
RSS04	34		138		3,220		25.40		159		1,880	J	3.0	
Group Tract	13		260		NA		2.10		NA		500		NA	
Ada North	9.8		77		NA		1.00	U	NA		120		NA	
RS01	10	U	100		1,100		1.00	U	27		190		5.0	U
RSS06 [1]	17		240		634		4.80		58		717	J	2	
N	18		18		13		18		13		18		13	
MIN	5		62		552		0.30		23		109		0.44	
MAX	51		412		11300		25		159		1880		5.0	
MEAN	20		157		2050		3.2		59		483		1.8	
GEOMEAN	17		134		1270		1.3		47		333		1.5	
MEDIAN	17		110		923		1.0		37		325		1.4	
STDEV	12		97		2930		6		44		479		1.2	
VARIANCE	152		9350		8.60E+06		34		1930		2.30E+05		1.4	
T-VALUE	1.74		1.74		1.74		1.74		1.74		1.74		1.74	
95% UCL	25		196		3460		5.6		80		679		2.3	
FREQUENCY	15/18		18/18		13/13		11/18		13/13		18/18		11/13	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limit.

J = Analyte detected above instrument detection limit but below contract required detection limit.

NA = Not analyzed

[1] Sample RSS06 was disturbed by road construction.

TABLE 3-6
WEST RICO FUTURE RESIDENTIAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Talus/Slope Wash (West) - Undisturbed														
RSS09	28		184	J	1130		4.1		40		647	J	0.5	U
RSS12	27		124	J	710		1.0		125		175	J	0.5	U
RSS13	21		78	J	1090		0.80		49		171	J	0.5	U
BK07	19		66		1020		1.3		53		161	J	1.0	
BK08	24		57		872		0.35	U	39		98	J	0.5	U
BK09	20		141		2120		3.3		42		683	J	1.0	
BK10	43		108	J	3430		1.1		24		398	J	1.0	
BK11	38		64	J	1500		0.35	U	45		167	J	0.5	U
BK12	23		441	J	1250		6.3		184		685	J	1.0	
RSS14 (1)	25		115	J	777		1.90		51		285	J	1	
RSS10 (2)	36		143	J	1,030		1.5		66		200	J	1.0	
RSS22 (2)	39		380		1,970		1.9		88		369		1.0	
N	12		12		12		12		12		12		12	
MIN	19		57		710		0.35		24		98		0.50	
MAX	43		441		3430		6.3		184		685		1.0	
MEAN	29		158		1410		2.0		67		337		0.79	
GEOMEAN	28		127		1270		1.4		57		277		0.75	
MEDIAN	26		120		1110		1.4		50		243		1.0	
STDEV	8		124		774		1.8		45		220		0.26	
VARIANCE	68		15500		599000		3.1		2070		48500		0.07	
T-VALUE	1.796		1.796		1.796		1.796		1.796		1.796		1.796	
95% UCL	33		223		1810		2.9		91		451		0.93	
FREQUENCY	12/12		12/12		12/12		10/12		12/12		12/12		7/12	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limit.

J = Analyte detected above instrument detection limit but below contract required detection limit.

(1) Sample RSS14 was disturbed by road construction.

(2) Samples RSS10 and RSS22 are from the Iron Draw Alluvial Fan Deposit.

TABLE 3-7
SILVER CREEK ALLUVIAL FAN RESIDENTIAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Silver Creek Alluvium - Disturbed														
RS21	10	U	3,400		2,900		38.0		240		5,300		18.0	
RS22	10	U	2,000		1,500		33.0		200		4,400		5.0	U
RS23	29		800		2,500		11.0		160		2,000		5.0	U
N	3		3		3		3		3		3		3	
MIN	10		800		1500		11		160		2000		5.0	
MAX	29		3400		2900		38		240		5300		18	
MEAN	16		2070		2300		27		200		3900		9.3	
GEOMEAN	14		1760		2220		24		197		3600		7.7	
MEDIAN	10		2000		2500		33		200		4400		5.0	
STDEV	11		1300		721		14		40.0		1706		7.5	
VARIANCE	120		1.69E+06		5.20E+05		200		1600		2.91E+06		56	
T-VALUE	2.92		2.92		2.92		2.92		2.92		2.92		2.92	
95% UCL	35		4260		3520		52		267		6780		22	
FREQUENCY	1/3		3/3		3/3		3/3		3/3		3/3		1/3	

TABLE 3-8
GRAND VIEW SMELTER FUTURE RESIDENTIAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
RSS08	56		3,460		2,690		16.7		724		2,120	J	47	
RS13	47		4,800		5,600		20		660		4,000		64	
96-CH-01	22		6,290		8,180		13.8		796		6,040		42.5	
N	3		3		3		3		3		3		3	
MIN	22		3,460		2,690		14		660		2120		43	
MAX	56		6,290		8,180		20		796		6,040		64	
MEAN	42		4,850		5,490		17		727		4,050		51	
GEOMEAN	39		4,710		4,980		17		725		3,710		50	
MEDIAN	47		4,800		5,600		17		724		4,000		47	
STDEV	17.6		1,420		2,750		3.1		68.0		1,960		11	
VARIANCE	310		2.00E+06		7.54E+06		9.6		4,630		3.84E+06		130	
T-VALUE	2.920		2.920		2.920		2.920		2.920		2.920		2.920	
95% UCL	71		7,240		10,100		22		841		7,350		70	
FREQUENCY	3/3		3/3		3/3		3/3		3/3		3/3		3/3	

J = Analyte detected above instrument detection limit but below contract required detection limit.

TABLE 3-9
RIVER CORRIDOR RECREATIONAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)		Pb (mg/Kg)		Mn (mg/Kg)		Cd (mg/Kg)		Cu (mg/Kg)		Zn (mg/Kg)		Ag (mg/Kg)	
Dolores River Corridor														
RSS15	32		424	J	2,560		5.7		84		927	J	26	
RSS16	25		471	J	894		6.7		93		860	J	3	
RS12	37		5,200		1,300		19.0		330		2,400		13	
RS19	28		12,000		800		23.0		260		3,700		21	
RS20	22		2,000		1,800		17.0		330		2,400		5	U
RS27	25		500		12,000		14.0		150		1,500		48	
RS25	40		1,200		1,200		4.0		200		1,100		12	
RS26	27		1,600		13,000		9.0		310		4,000		41	
RS28	10	U	3,500		2,000		17.0		420		2,600		14	
RSS19	98		6,180	J	529		9.2		641		1,520	J	34	
RSS11	56		124		1,900		1.2		94		226	J	2	
RSS35	16		146		1,020		2.6		46		360	J	0.5	U
RSS01	35		346		944		1.8		76		249	J	3	
N	13		13		13		13		13		13		13	
MIN	10		124		529		1.2		46.0		226		0.50	
MAX	98		12,000		13,000		23		641		4,000		48	
MEAN	35		2,590		3,070		10		233		1,680		17	
GEOMEAN	30		1,100		1,760		7.1		178		1,180		9.2	
MEDIAN	28		1,200		1,300		9.0		200		1,500		13	
STDEV	22		3,450		4,230		7.2		172		1,250		16	
VARIANCE	493		1.19E+07		1.79E+07		53		2.96E+04		1.57E+06		250	
T-VALUE	1.782		1.782		1.782		1.782		1.782		1.782		1.782	
95% UCLM	46		4,300		5,160		14		318		2,300		25	
FREQUENCY	12/13		13/13		13/13		13/13		13/13		13/13		11/13	

U = Analyte not detected at or above detection limit. Value presented is one half the detection limit.

J = Analyte detected above instrument detection limit, but below contract required detection limit.

TABLE 3-10
WASTE ROCK RECREATIONAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
RSS32 (Van Winkle)	24	7,960	5,410	119	494	18,200	27
Sam Patch	26	12,000	NA	17	NA	2,900	NA
RP-01 (Laura)	74	8,500	1,200	60	590	9,000	220
RP-03 (Atlantic Cable)	26	7,000	5,000	84	570	13,000	68
96-CH-03	8.5	18,600	8,770	276	1,360	37,900	52
N	5	5	4	5	4	5	4
MIN	8.5	7,000	1,200	17	494	2,900	27
MAX	74	18,600	8,770	280	1,360	37,900	220
MEAN	32	10,800	5,100	110	754	16,200	92
GEOMEAN	25	10,100	4,110	78	689	11,900	68
MEDIAN	26	8,500	5,210	84	580	13,000	60
STDEV	25	4,750	3,100	99	406	13,400	87
VARIANCE	610	2.25E+07	9.59E+06	9,900	1.65E+05	1.78E+08	7,600
T-VALUE	2.132	2.132	2.353	2.132	2.353	2.132	2.353
95% UCL	55	15,300	8,750	210	1,230	29,000	190
FREQUENCY	5/5	5/5	4/4	5/5	4/4	5/5	4/4

NA = Not analyzed

TABLE 3-11
ROADFILL RECREATIONAL SOILS DATA
RICO, COLORADO

SAMPLE NUMBER	As (mg/Kg)	Pb (mg/Kg)	Mn (mg/Kg)	Cd (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)	Ag (mg/Kg)
RSS21	31	1,760	1,650	23.7	221	2,860	12
RSS29	35	2,430	2,390	49.0	221	6,100	11
RSS33	25	368	1,210	6.2	87	1,100	2
Smuggler	12	420	NA	2.2	NA	460	NA
Hillside #2	24	9,100	NA	16.0	NA	2,400	NA
Hillside	26	2,800	NA	23.0	NA	3,400	NA
Home	21	300	NA	4.6	NA	780	NA
96-CH-02	3.5	2,260	2,470	37.8	264	5,080	15.6
96-CH-04	32	2,300	2,490	46.9	243	5,580	10.2
N	9	9	5	9.0	5	9	5
MIN	3.5	300	1,210	2.2	87.0	460	2.0
MAX	35	9,100	2,490	49	264	6,100	16
MEAN	23	2,420	2,040	23	207	3,080	10
GEOMEAN	20	1,440	1,970	15	194	2,270	8.4
MEDIAN	25	2,260	2,390	23	221	2,860	11
STDEV	10	2,690	581	18	69.5	2,120	5.0
VARIANCE	*100*	*7.24E+06*	*3.38E+05*	*320*	*4,830*	*4.51E+06*	*25*
T-VALUE	1.860	1.860	2.132	1.860	2.132	1.860	2.132
95% UCL	30	4090	2590	34	273	4,390	15
FREQUENCY	9/9	9/9	5/5	9/9	5/5	9/9	5/5

NA = Not analyzed

of samples representative of background (Tables 3-2 and 3-4) follows the discussion presented above in Section 2.6.7.

3.2 Comparison of Metals Concentrations in Rico Soils to State/EPA Guidance Levels

Because no screening criteria or standards are available from the State of Colorado, site soil concentrations at Rico were compared to EPA and screening levels from other states. Seven different guidance criteria were used in this comparison:

"Draft Soil Screening Guidance" from EPA's Office of Solid Waste and Emergency Response (hereafter called the OSWER values) (U.S. EPA, 1994a).

EPA Region III "Risk-Based Concentration Table" (hereafter called EPA Region III values) (U.S. EPA, 1995a).

Arizona Department of Environmental Quality (ADEQ). The Arizona Department of Environmental Quality (ADEQ) Health Based Guidance Levels (HBGLs) (ADEQ, 1995).

Texas Natural Resource Conservation Commission (TNRCC). The Texas Natural Resource Conservation Commission (TNRCC) Soil Clean-up Standards (GSI, 1993).

Michigan Department of Environmental Quality (MDEQ). The Michigan Department of Environmental Quality (MDEQ) guidance levels, "Generic Residential Cleanup Criteria" as presented in *"Interim Environmental Response Division Operational Memorandum #8, Revision 4, June 1995"* (MDEQ, 1995).

These guidance levels are presented in Table 3-12. The guidance levels are generally conservative (i.e., health protective) values that represent a level of contamination below which there is no concern. All of the guidance levels were based on residential exposures. With the exception of MDEQ values, for carcinogens, the target risk level for the values is 1×10^{-6}. For noncarcinogens, the target risk is that the potential daily dose from soil not exceed a threshold value, termed a reference dose, below which no adverse health effects are expected. Generally, if contaminant concentrations in soil fall below the screening values, then no further study or action is warranted for residential use of that area (U.S. EPA, 1994a). Concentrations in soil above the screening level would not automatically trigger a response action. However, exceeding a screening level suggests that a further evaluation of the potential risks posed by site contaminants is appropriate to determine the need for a response action (U.S. EPA, 1994a). A complete discussion regarding background concentrations of metals was provided in Section 2.6.7. This discussion provides a detailed explanation of the soil samples which represent background in the Rico area. These samples are used for comparison to guidance levels in the following discussion.

TABLE 3-12
COMPARISON OF METALS CONCENTRATIONS IN RICO SOILS WITH STATE/ EPA GUIDANCE LEVELS

GUIDANCE	Arsenic (mg/Kg)	Cadmium (mg/Kg)	Copper (mg/Kg)	Lead (mg/Kg)	Manganese (mg/Kg)	Silver (mg/Kg)	Zinc (mg/Kg)
EPA, Region III[1]	0.37	39	2,900	---	390	390	23,000
EPA, 1994a[2]	0.43	39	---	---	---	390	23,000
ADEQ, 1995[3]	0.91	58	4,300	400	580	580	35,000
MDEQ, 1995[4]	6.6	2,100	---	400	2,000	2,400	140,000
TNRCC, 1993[5]	0.366	137	---	500	---	1370	---
RICO SOILS							
North Rico Residential							
Mean	28	16	171	1,790	2,000	8.5	2,450
95% UCLM	34	23	205	2,370	2,550	12	3,210
South Rico Residential							
Mean	23	8.4	120	783	1,880	6.5	1,470
95% UCLM	29	9.7	139	940	2,510	7.9	1,690
North Rico Background Data							
Mean	17	11	190	1,540	2,440	4.1	2,010
95% UCLM	20	16	271	2,490	3,620	5.2	2,680
South Rico Background Data							
Mean	24	6.9	163	744	1,810	5.5	1,120
95% UCLM	43	10	252	1,240	2,540	11	1,710
Future Residential - Grand View Smelter							
Mean	42	17	727	4,850	5,490	51	4,050
95% UCLM	71	22	841	7,270	10,100	70	7,360
Future Residential-Slope Wash East							
Mean	20	3.2	59.0	157	2,050	1.8	483
95% UCLM	25	5.6	80.2	196	3,470	2.3	679
Future Residential-Slope Wash West							
Mean	29	2.0	67.0	158	1,410	0.80	337
95% UCLM	33	2.9	91.0	223	1,810	0.90	451
Future Residential - Silver Creek Alluvium							
Mean	16	27	200	2,070	2,300	9.3	3,900
95% UCLM	35	52	267	4,260	3,520	22	6,780
Recreational - Dolores River Corridor							
Mean	35	10	233	2,590	3,070	17	1,680
95% UCLM	46	14	318	4,300	5,160	25	2,300

[1]EPA, 1994a. EPA Region III Risk-Based Concentration Table, First Quarter 1994 Memo from Roy L. Smith.

[2]EPA, 1994b. Soil Screening Guidance, Draft. Office of Solid Waste and Emergency Response. Values are based on soil ingestion for a residential exposure scenario. Cancer risks are based on a risk of 1 X 10^{-6} and noncancer risks are based on a hazard quotient of 1. This document states that where background concentrations are greater than the Soil Screening Level (SSLs), the SSLs generally will not be the best tool for site decision making.

[3]Arizona Department of Environmental Quality (ADEQ) 1995. Interim Soil Remediation Standards, July 1995. Values are based on soil ingestion for a residential exposure scenario. Cancer risks are based on a risk of 1 X 10^{-6} for carcinogens and a hazard quotient of 1 for noncarcinogens.

[4]Michigan Department of Environmental Quality (MDEQ). 1995. Generic Residential Cleanup Criteria. Values are based on soil ingestion for a residential exposure scenario. Cancer risks are based on a risk of 1 X 10^{-5} and noncancer risks are based on a hazard quotient of 1.

[5]Groundwater Services Inc., 1993. Values are based on soil ingestion for a residential exposure scenario. Cancer risks are based on a risk of 1 X 10^{-6} and noncancer risks are based on a hazard quotient of 1

--- = Not Available

Table 3-12 presents a comparison of metals concentrations in Rico soils with the State and EPA guidance levels. The OSWER, EPA Region III, TNRCC, MDEQ and ADEQ values are based on soil ingestion for a residential scenario. The guidance levels vary due to different exposure assumptions and risk estimates that were used to calculate the soil concentrations. The Upper Confidence Limit on the Mean (UCLM) value was considered as the appropriate measure for comparison, because this value represents a conservative upper estimate of the concentration to which an individual in Rico might be exposed over time. The UCLM is the value that EPA recommends for use as the exposure point concentration in conducting risk assessments (U.S. EPA, 1989a). It is, therefore, the appropriate value to use in comparison to the EPA's risk-based screening levels.

For comparison, Table 3-12 also presents the UCLM and mean concentrations for metals in samples representative of specific exposure areas. As Table 3-12 indicates, the UCLM values for cadmium, copper and zinc for all exposure areas are below soil screening levels for these metals. Site concentrations of arsenic, lead and manganese, however, exceed at least one of the soil screening values. It should be noted that, arsenic concentrations in surficial soils in Colorado range from 1.2 to 24 mg/kg (mean of 5.4 mg/kg, n=168; Dragun and Chiasson, 1991). Therefore, any soil sample collected in Colorado would most likely exceed the OSWER and EPA screening values, as these values are below background concentrations for arsenic in Colorado soils. In addition, comparison of the background arsenic concentrations collected from Rico soils indicates that the site-specific background arsenic concentrations also exceed the OSWER and EPA Region III screening values. The UCLM arsenic concentrations in North and South background soils are 20.1 and 43.0 mg/kg, respectively. The screening values for arsenic range from 0.37 to 6.6 mg/kg. Background concentrations for lead and manganese also exceed guidance levels. As Table 3-11 indicates, the background UCLM concentrations for lead are 2,490 and 1,240 mg/kg for North and South background soils, respectively. The background UCLM concentrations for lead exceed all guidance values presented in Table 3-12. Screening levels for lead range from 400 to 500 mg/kg. Similarly, for manganese, the UCLM concentrations in background bedrock and soils exceed the guidance limits recommended by EPA Region III and MDEQ. Background concentrations of manganese in North and South Residential areas were 3,620 and 2,540 mg/kg, respectively. Guidance levels for manganese range from 390 to 2,000 mg/kg.

Although the UCLM value for residential samples was chosen for comparison to the standards, it is important to point out that UCLM soil concentrations for samples collected from the river corridor area, which represents a recreational rather than residential exposure scenario, also fall below screening levels for cadmium, copper, silver, and zinc. Because concentrations of cadmium, copper, silver, and zinc in the residential and recreational areas are all below the soil screening levels, it is concluded that these compounds present no threat to human health at the site under any land use scenario. Therefore, these metals are not evaluated further in this application.

3.3 Background Analysis

3.3.1 T-Test Analysis

A statistical comparison was performed for arsenic, lead and manganese in order to determine if current residential soils in North and South Rico are statistically similar to background concentrations for these areas. The T-test statistic is used to test the equality (or similarity) of the population mean. If two soil sample populations have statistically similar means, then the populations are considered similar at a given statistical significance level. Appendix C presents a detailed explanation of the T-Test as well as the calculations and results.

Table 3-13 summarizes the results of the T-test. In general, the background analysis indicates that there are similarities between arsenic, lead and manganese concentrations in the background residential soils and residential exposure areas.

3.4 Comparison to Background Values

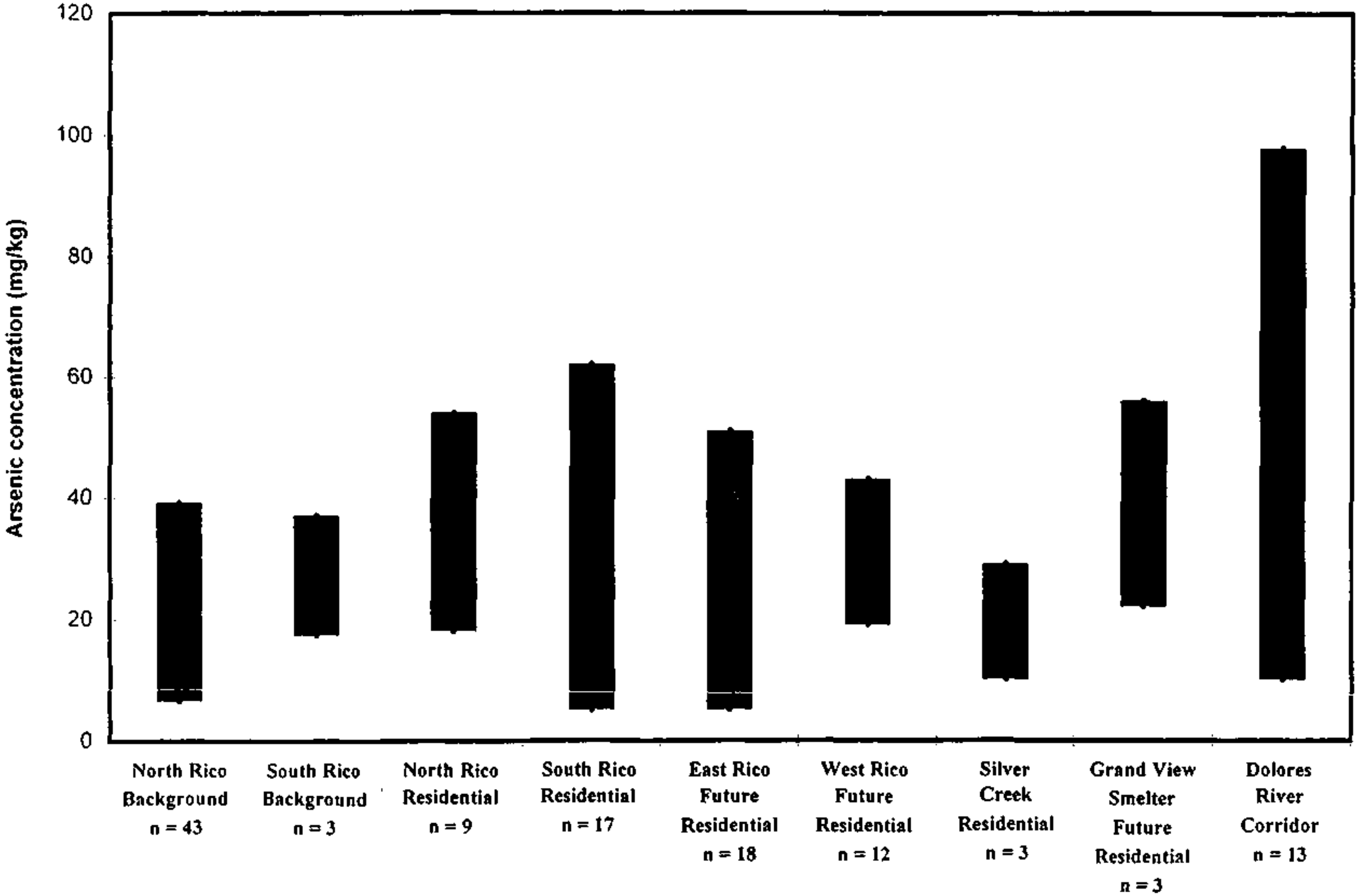
As discussed in Section 3.2, arsenic, lead and manganese exceed at least one of the soil screening criteria listed in Table 3-12. Table 3-14 provides a summary comparison of residential soils compared to background levels. The derivation of background levels has been previously discussed in Section 2.6.7 and 3.1 Both State and EPA screening criteria refer to comparison of site soils data to background levels, with background generally becoming the criteria for action when it is greater than regulatory default soil levels. Figures 3-2 through 3-4 provide a graphical presentation of background concentrations of metals compared to site-specific levels. A discussion of the results of background comparison of the exposure areas are outlined below.

3.4.1 Arsenic

Table 3-14 presents UCLM and mean concentrations for each exposure area. The UCLM for arsenic for North Rico Residential Background is 20 mg/kg. The UCLM for arsenic in the North Rico Residential area is 34 mg/kg. Although UCLM arsenic concentrations exceed UCLM background concentrations in the North Rico Residential Area, results of the T-tests indicate that arsenic concentrations between the two areas are statistically similar at a 95% confidence level. In addition, the correlation coefficient for arsenic concentrations with base metals indicate that arsenic is not associated with the ore body (see Figure 2-30). These results suggest that the arsenic concentrations in Rico residential soils are naturally occurring and distributed throughout the Rico District (see Section 2.6.7).

The UCLM for arsenic in the South Rico Background samples is 43 mg/kg. The UCLM for arsenic in the South Rico Residential area is 29 mg/kg. Background concentrations of arsenic exceed arsenic concentrations in the South Rico Residential Exposure Area. Although there are

FIGURE 3-2
Range of Arsenic Concentrations versus Exposure Areas



MRANGE.XLS4/11/96

FIGURE 3-3
Range of Manganese Concentrations versus Exposure Areas

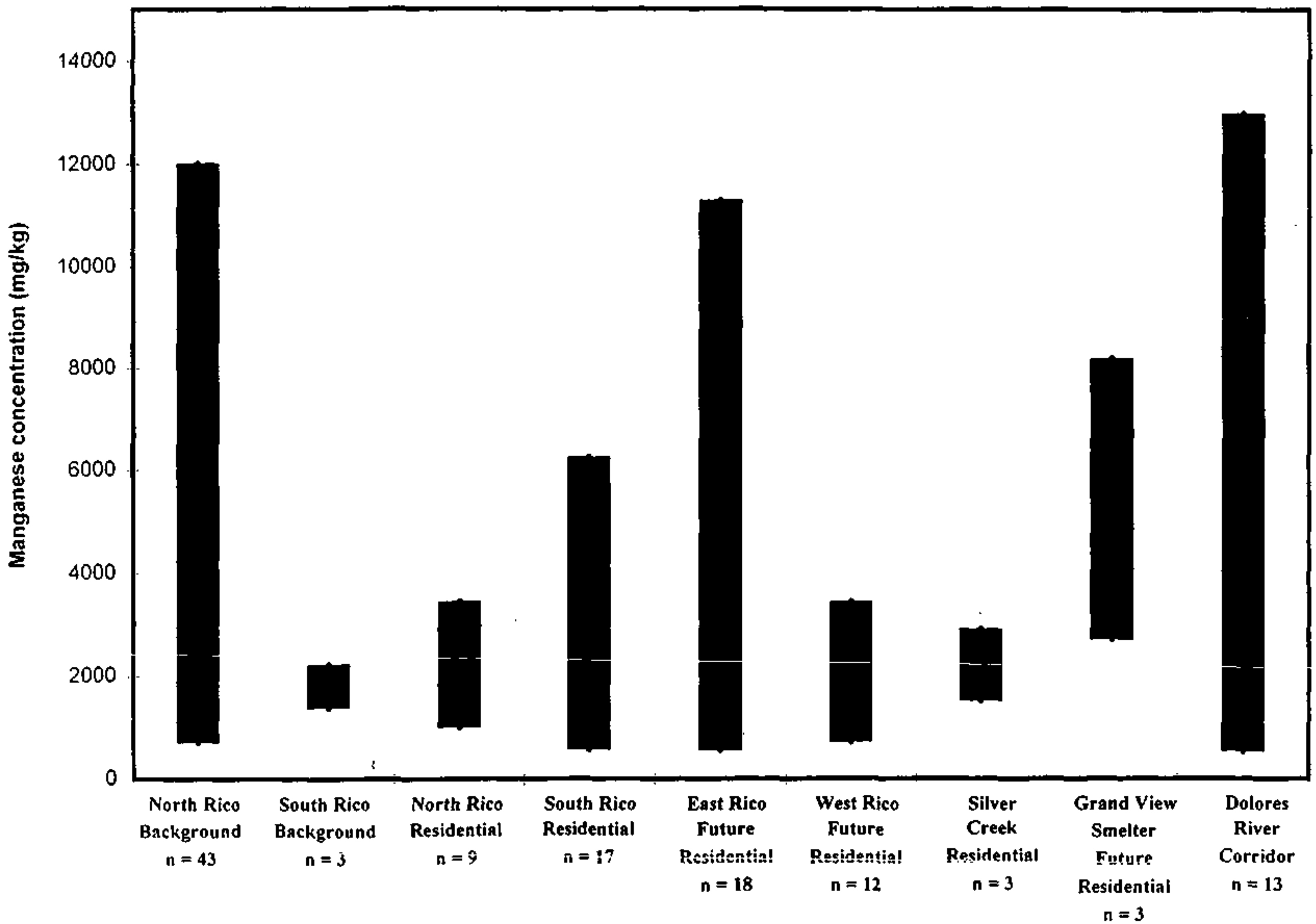


FIGURE 3-4
Range of Lead Concentrations versus Exposure Areas

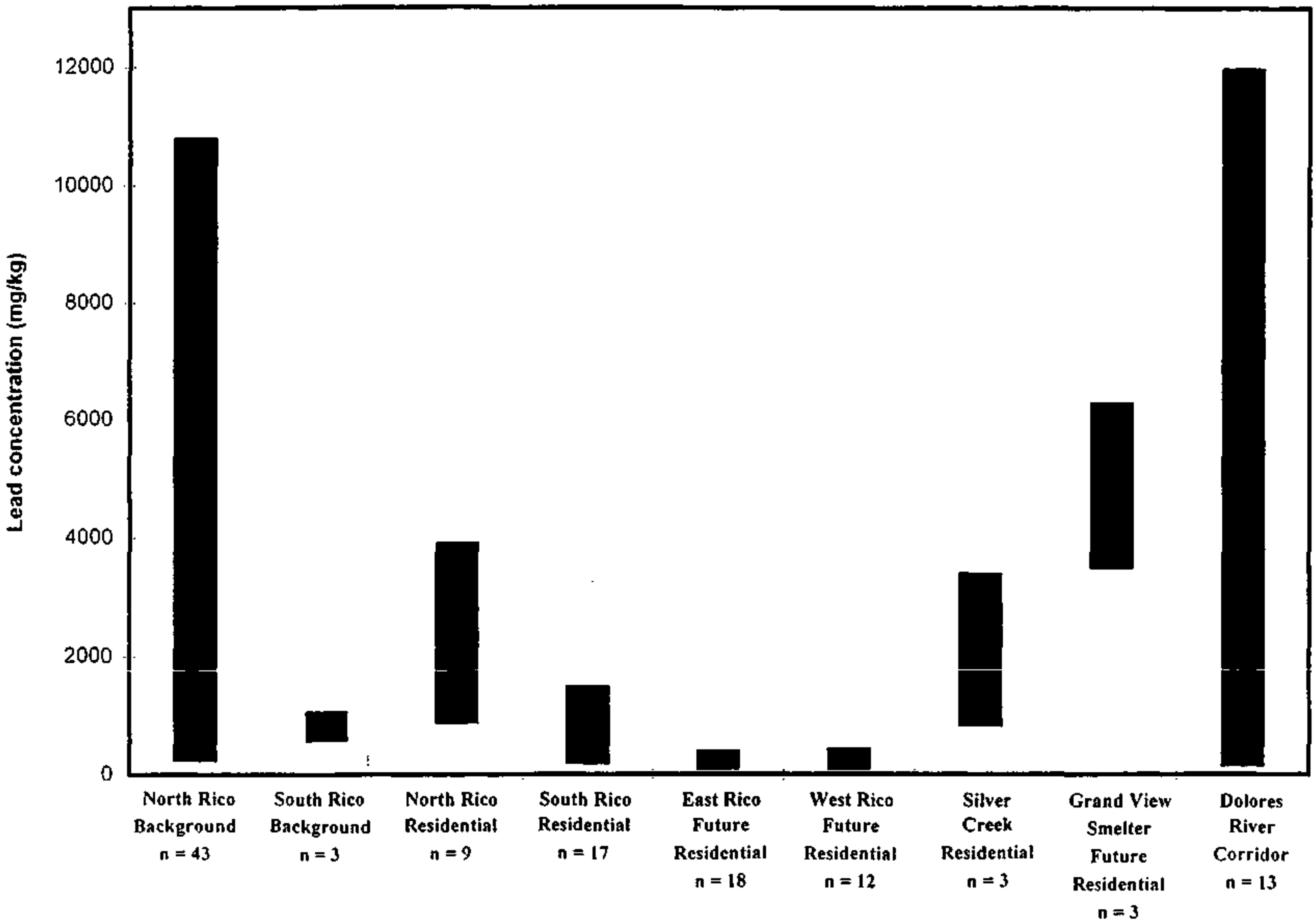


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TABLE 3-13
SUMMARY OF T-TEST RESULTS FOR COMPARISON OF METALS CONCENTRATIONS IN SOILS WITH BACKGROUND

	T-TEST RESULTS	SIMILAR TO BACKGROUND?
RICO NORTH RESIDENTIAL WITH RICO NORTH BACKGROUND		
Arsenic	PASS	YES
Manganese	PASS	YES
Lead	PASS	YES
RICO SOUTH RESIDENTIAL WITH RICO SOUTH BACKGROUND		
Arsenic	PASS	YES
Manganese	PASS	YES
Lead	PASS	YES

TABLE 3-14
RICO COMMUNITY SOILS
COMPARISON OF RICO SOILS DATA IN THE RESIDENTIAL AREAS

Sample Categories	Number of Samples	Arsenic		Lead		Manganese	
		Mean (Range) (mg/Kg)	95% UCLM (mg/Kg)	Mean (Range) (mg/Kg)	95% UCLM (mg/Kg)	Mean (Range) (mg/Kg)	95% UCLM (mg/Kg)
North Rico Background Residential Data	43	16.7 (2.5 - 80.2)	20.1	1,540 (13.0 - 39,700)	2,490	2,440 (168 - 33,200)	3,620
South Rico Background Residential Data	3	23.9 (17.3 - 37.0)	43.0	744 (554 - 1,080)	1,240	1,810 (1,370 - 2,230)	2,540
North Rico Residential	9	27.7 (18.0 - 54.1)	34.4	1,790 (851 - 3,920)	2,370	2,000 (1,000 - 3,450)	2,550
South Rico Residential	17	22.8 (5.0 - 62.0)	28.5	783 (160 - 1,500)	940	1,880 (564 - 6,240)	2,510
East Rico Future Residential	18	20.2 (5.0 - 51.0)	25.2	157 (62.0 - 412)	196	2,050 (552 - 11,300)	3,470
West Rico Future Residential	12	29.0 (19.0 - 43.0)	33.0	158 (57.0 - 441)	223	1,410 (710 - 3,430)	1,810
Silver Creek Alluvium Future Residential	3	16.0 (10.0 - 29.0)	35.0	2070 (800 - 3400)	4260	2300 (1500 - 2900)	3520
Grand View Smelter Future Residential	3	42.0 (22.0 - 56.0)	71.0	4,850 (3460 - 6290)	7,240	5,490 (2690 - 8180)	10,100

only three samples which represent background soil concentrations for South Rico, the mean values for metals are very similar to those for the disturbed ancestral alluvium in the same south Rico area (see Table 2-13).

Figure 3-2 presents a graphical display of arsenic concentrations for each area. As Figure 3-2 indicates, with the exception of the River Corridor, arsenic concentrations in all areas are very similar to those found in background areas.

3.4.2 Manganese

The background UCLMs for manganese are higher than manganese UCLMs in all other areas with the exception of recreational soils in the River Corridor (see Figure 3-3). All soil samples collected from residential areas in Rico exhibit manganese concentrations (range of 529 to 13,000 mg/kg) that are lower than the maximum background concentrations for North Rico (33,200 mg/kg). Figure 3-3 presents a graphical display of concentrations of manganese for each area. Concentrations of manganese in each exposure area fall within the range of background concentrations of manganese. Manganese concentrations in the residential areas range from 550 to 11,300 mg/kg whereas manganese concentrations in background soils range from 160 to 33,200 mg/kg.

3.4.3 Lead

The UCLM for lead for the North Rico Residential Exposure Area (2,370 mg/kg) is less than the UCLM for lead in the North Rico background samples (2,490). Similarly, the UCLM for lead in South Rico Residential Exposure Area (940 mg/kg) is less than the UCLM for lead in the South Rico background samples (1,240 mg/kg). These data indicate that lead concentrations for the North and South Residential Exposure Areas are below the background levels for these areas and therefore, represent naturally-occurring concentrations.

The UCLM values for lead (see Table 3-14) in the East and West Future Residential Exposure Areas (196 and 220 mg/kg, respectively) are low and represent undisturbed naturally-occurring concentrations in these areas.

Figure 3-4 presents a graphical display of lead concentrations for each area. With the exception of the River Corridor, lead concentrations for each area fall within the range of North Rico background concentrations of lead. These comparisons indicate that concentrations of lead are naturally occurring.

3.5 Risk Assessment

The following presents the procedures, methods, and site-specific data used to evaluate potential risks to human health from exposure to soils and dust within the exposure areas in Rico.

3.5.1 Methodology and Scope

The purpose of the Health Risk Assessment (HRA) is to identify the impacts to people that may occur as a result of exposure to metals in soils at Rico. The HRA contributes to the site characterization and subsequent development, evaluation, and selection of appropriate actions. The HRA provides decision-makers with a characterization of constituents at the site that may pose a health threat, the potential routes of exposures, and a technical evaluation of the potential impacts to individuals residing at the site. In short, the HRA serves as a means of compiling all available scientific information about the conditions of the site in a manner which allows decision makers to select the best remedy for the site.

The HRA follows the guidance in *Risk Assessment Guidance for Superfund (RAGS)* (EPA 1989a). This document provides detailed guidance for estimating potential risks from contaminants in soils, groundwater, surface water, and air and is recommended by state and federal agencies for use in conducting an HRA.

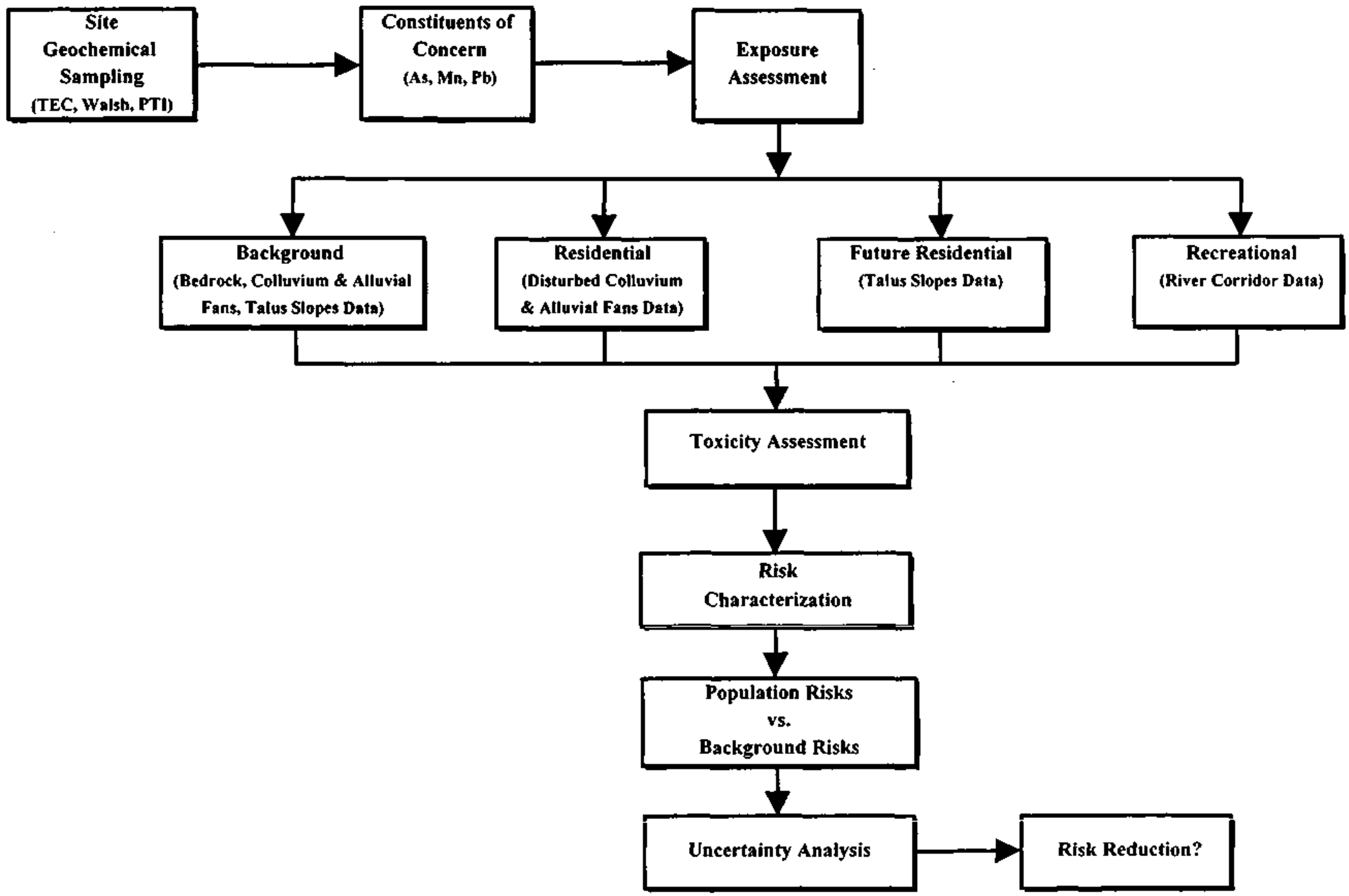
A risk assessment involves a series of steps (Figure 3-5). As Figure 3-5 indicates, there are four major steps in the risk assessment process; (1) data collection and identification of constituents of concern; (2) exposure assessment; (3) toxicity assessment and (4) risk characterization. The first step, data collection and identification of constituents of concern, involves gathering and analyzing the data relevant to the HRA and identifying the substances present at the site that are the focus of the HRA process. The second step, the exposure assessment, is conducted to estimate the magnitude of actual and/or potential human exposures, the frequency and duration of these exposures and the pathways by which humans are potentially exposed. The toxicity assessment component of the HRA process considers the types of adverse health effects associated with constituent exposures and the relationship between the magnitude of exposure and adverse health effects. The final step of the HRA, risk characterization summarizes and combines outputs of the exposure and toxicity assessments to characterize baseline risk, both in quantitative and qualitative terms.

The following sections describe the HRA process in detail for the Rico site.

3.5.2 Identification of Constituents of Concern

The identification of constituents of potential concern (COPC) is the phase of the HRA in which constituents that are likely to pose significant risks and health hazards are identified. EPA

Figure 3-5
Rico Community Soils
Health Risk Assessment Process



guidance (1989a) suggests that steps be taken to eliminate chemicals in order to make the risk assessment more understandable to the general public. EPA suggests applying the following information to the chemical data to eliminate nonhazardous constituents from the HRA:

- Essential nutrient information
- Frequency of detection
- Background concentration for inorganic chemicals

Although the EPA recommends that these factors be considered for selection of COPC, arsenic, manganese and lead have been previously identified in Section 3.2 as the only constituents which exceed the screening levels presented in Table 3-12. Therefore, arsenic, manganese and lead will be retained as COPC and quantitatively evaluated in the risk assessment.

It should be noted, however, that the background analysis described in Section 3.3 indicates that concentrations of arsenic, manganese and lead are not present at concentrations above background levels as indicated by comparison of concentrations to background areas and results of the *t*-test. Although concentrations for these metals are similar to background concentrations, for purposes of completeness and conservatism, these metals will be retained in the risk assessment.

3.5.3 Exposure Assessment

This section describes how residents and recreational users in the town of Rico may be exposed to metals in soils and dust, identifies potential exposure pathways under current and future use scenarios and quantifies chemical intake for each pathway.

3.5.3.1 Description of Exposure Areas

As described in Sections 3.14 and 2.6, the exposure areas identified for the risk assessment were based on surficial geology and expected land-use in Rico. As Section 3.14 previously described, there are six distinct exposure areas that can be identified within Rico. These areas are as follows: North Rico Residential, South Rico Residential, Future Residential West, Future Residential East, River Corridor, and the Silver Creek Alluvial Fan (Figure 3-1). In addition, exposure scenarios and risk evaluations are also developed for locally present roadfill, mine waste rock, and smelter waste at the Grand View smelter site.

As previously discussed, land-use is an important consideration in the identification of exposure areas. With the exception of the River Corridor, all other areas are either currently residential or may be designated for future residential use. Therefore, all areas except the River Corridor were evaluated for residential use. The River Corridor has been evaluated for recreational use in the risk assessment. The data for the roadfill, and waste rock were used to evaluate recreational exposures as well. It is possible that an individual may hike on or near the waste rock areas and subsequently be exposed to soil. Although dirt bike riders have not been observed in the Rico area, for purposes of conservatism and due to the fact that roads in Rico are not paved, roadfill data were used to evaluate potential exposures to a dirt bike rider.

Because parts of the Grand View Smelter site may be developed as residential, a residential exposure scenario was used to assess risk at this site.

In addition to the evaluation of residential exposures for North Rico Residential, South Rico Residential, Future Residential East, and Future Residential West, exposures and risks for samples representative of North and South Rico Background were evaluated due to the naturally-occurring metals in these residential areas.

3.5.3.2 Exposure Pathways

An exposure pathway is defined by the following four elements:

- A source and mechanism of chemical release to the environment
- An environmental transport medium for the released chemical
- A point of potential exposure by the receptor with the medium
- A route of exposure

An exposure pathway is considered "complete" only if all of these elements are present. Children and adults typically ingest small amounts of soil and dust through hand-to-mouth contact. Therefore soil ingestion is considered complete for residents and recreational users. Because contaminants present in soil may be transported indoors, children and adults may be exposed to small amounts of soil and dust in the house. Therefore, ingestion of house-dust has been included in this evaluation. It is likely that residents and recreational users might have dermal contact with soils. However, only limited data are available on the rate at which metals cross the skin into the blood from soil or dust particles; therefore, dermal exposure to metals was not evaluated in the risk assessment. It is not likely that omission of this pathway results in a significant underestimate of risk because uptake of metals across the skin, particularly from soil, is generally believed to be minor relative to exposures from soil ingestion and dust inhalation. Inhalation of house-dust was not evaluated for residents or recreational users as this pathway is considered insignificant compared to soil and dust ingestion. As a subset of recreational users, a dirt bike rider was evaluated as there is a small likelihood that individuals may use the dirt roads for dirt bike riding, resulting in exposure to soils by ingestion and inhalation. The following exposure pathways were, therefore, considered complete and were quantified in this HRA:

- Ingestion of soil (recreational and dirt bike rider)
- Ingestion of soil and house-dust (residential)
- Inhalation of dust from roads (dirt bike rider)

3.5.3.3 Estimated Metal Intake

EPA risk assessment guidance (1989a) recommends that chemical intake be estimated so that the estimated risks are for the reasonable maximum exposure (RME). The RME risk represents the upper-bound risk. It is unlikely that under actual exposure conditions the RME risk estimated in this HRA will be exceeded. The following sections present the algorithms used to evaluate exposures to metals in soils and provides an explanation for the derivation of exposure parameters. Table 3-15 provides a summary of exposure parameters used in the algorithms.

Ingestion of Soils and Dust for Residents and Recreational Users:

Exposure estimates for intakes are based on the mass of a chemical taken into the body per body weight per unit time. The following algorithms were used to estimate chronic daily intake via soil and house-dust ingestion for residents. Ingestion of soil only was evaluated for recreational users.

$$CDI = [C_s \times IR_c \times CF \times FI \times EF_c \times ED_c \times BAF)/(BW_c \times AT_c)] +$$

$$[(C_s \times IR_A \times CF \times FI \times EF_A \times ED_A \times BAF)/(BW_A \times AT_A)]$$

where:

CDI = Chronic Daily Intake (mg/kg/day)
Cs = 95% UCLM for each metal (mg/kg)
AT = Averaging Time (A = Adult, C = Child) (days)
CF = Conversion Factor (kg/mg)
EF = Exposure Frequency (A = Adult, C = Child) (days/year)
ED = Exposure Duration (A = Adult, C = Child) (year)
FI = Fraction Ingested from Contaminated Source (unitless)
IR = Soil Ingestion Rate (A = Adult, C = Child) (mg/day)
BAF = Bioavailability Factor for Soil (unitless)
BW = Body Weight (A = Adult, C = Child) (kg)

Soil Ingestion and Dust Inhalation by a Dirt Bike Rider:

Because dirt bike riding is likely to entrain elevated amounts of dust from the dirt roads, inhalation of road dust by a dirt bike rider was evaluated in addition to soil ingestion. The following equation was used to estimate chronic daily intake by a dirt bike rider:

$$CDI = (C_s \times EF \times ED \times [(IR_s \times CF_s \times BAF_s) + (IR \times DL \times ET)])/ (BW \times AT)$$

where:

CDI = Chronic Daily Intake (mg/kg/day)
Cs = 95% UCLM for each metal (mg/kg)
AT = Averaging Time (days)
CF = Conversion Factor (kg/mg)
EF = Exposure Frequency (days/year)
ED = Exposure Duration (year)
FI = Fraction Ingested from Contaminated Source (unitless)
IR = Soil ingestion rate (mg/day)
BAF = Bioavailability Factor for Soil (unitless)
BW = Body Weight (kg)
IR = Inhalation Rate (m^3/hr)
DL = Dust Loading Factor (kg/m^3)
ET = Exposure Time (hr/day)

It was assumed that a dirt bike rider would be a teenager or adult, therefore, exposure parameters are representative of an adult.

EPA-derived default values, which are based on national statistics for the general population, were used to estimate chemical intake. Following is a description of the derivation of each exposure assumption.

Exposure Point Concentration: As recommended by EPA, the 95% upper confidence limit on the mean concentration in soil was used as the exposure point concentration. This is a conservative estimate, as it is a number that equals or exceeds the true mean 95 percent of the time. For exposure to dust, previous data (CDM, 1995) indicate that metals concentrations in household dust are approximately 44% of metals concentrations in soils. In addition, the background concentration of a metal in household dust is assumed to be approximately 1% of the metal concentration in soil.

Exposure Frequency: The exposure frequency (EF) for ingestion of soils is 256 days per year for residential exposures. This number assumes that three months of the year, the ground is either frozen or covered with snow, making exposure to soils unlikely. In addition, it was assumed that two weeks of the year are spent away from home on vacation (9 months x 30 days/month = 270 days, 270-14 = 256 days/year). The exposure frequency for ingestion of dust, however, is 350 days per year which takes into account two weeks spent away from the home per year. The exposure frequency for recreational users was estimated to be 72 days per year. This number assumes that an individual may visit the recreational areas twice per week for 9 months of the year. The remaining three months of the year the ground is either covered with snow or frozen, and temperatures are most likely not appropriate (i.e., low temperatures) for recreational activities in these areas.

Exposure Duration: Exposure durations of 24 and 6 years were used for adults and children, respectively. These values are recommended by EPA (1993) and assume that an individual may live at one residence for 30 years. An exposure duration of 30 years was assumed for the recreational users.

Soil Ingestion Rate: The residential soil ingestion rates recommended by EPA (1993) are 200 mg/day for children ages 1 through 6 and 100 mg/day for adults and others. The soil ingestion rate for recreational users is 100 mg/day.

Bioavailability Factors for Soil and Dust: The bioavailability of arsenic has recently been investigated (Freeman, et al. 1995). This study indicated that absorption of arsenic from soils and dust is significantly less than absorption of soluble arsenic from water. The study titled "Determination of the Bioavailability of Soluble Arsenic and Arsenic in Soil and Dust Impacted by Smelter Activities Following Oral Administration in Cynomolgus Monkeys", presented blood arsenic, urine arsenic and feces arsenic data collected from Cynomolgus monkeys exposed to arsenic by intravenous injection, gavage and capsules containing soil and dust. The absolute bioavailability estimated from blood arsenic concentrations ranged between 91 and 100 percent for gavage, 11 and 18 percent for soil ingestion and 8 and 11 percent for dust. Based on the study results, EPA derived arsenic bioavailability estimates for ingested soil and dust (U.S. EPA 1994b, 1995b). These BAFs have been used at similar sites such as the Anaconda Smelter Site (CDM, 1995). The bioavailability value selected for dust absorption was 25.8 percent and for soil absorption was 18.3 percent. These values were used in this assessment. Bioavailability of manganese was assumed to be 50% although data indicate that bioavailability may range from 0.8 - 16% (Davidsson et al., 1989).

Fraction Ingested: The FI values used for adults and children include both soil and interior dust. The fraction ingested (FI) values correct for the relative amount of soil or dust ingested. It was assumed for both adults and children that of the total soil and dust ingested, 55% derived from indoor dust and 45% derived from soil. These values follow EPA guidance.

Inhalation Rate: EPA (1989b) presents inhalation rates for adults. Moderate activity was assumed for the dirt bike rider scenario. The inhalation rate for moderate activity is 2.5 m^3/hour.

Averaging Time: When evaluating long-term exposure to noncarcinogenic compounds, exposures were calculated by averaging over the period of exposure (i.e., subchronic or chronic exposures). For carcinogenic compounds, exposures were calculated by prorating the total cumulative dose over a lifetime (also called lifetime average daily dose). The averaging times for carcinogens for residential and recreational exposure were 25,550 days (70 years x 365 days/year). For noncarcinogens, the averaging times were 8,760 days (24 years x 365 days/year) and 2,190 days (6 years x 365 days/year) for adults and children respectively, for recreational and residential receptors.

Dust Loading Factor: Dust loading during dirt bike riding was estimated using an approach developed by Life Systems (1993). The calculations are provided in Appendix F.

Exposure Time: The exposure time for a dirt bike rider was based on professional judgment and assumed to be 5 hours per day.

The exposure values recommended by U.S. EPA guidance represent a mix of high-end and mid-range values. These assumptions result in a reasonable maximum exposure (RME) for residential and recreational exposure occurring at the Rico site. The algorithms for each scenario are presented in Appendix D.

3.6 Risk Characterization

The purpose of the risk characterization is to estimate the potential for exposure to contaminants to cause adverse effects in individuals and to provide an estimate of the dose-response relationship between the extent of exposure to the contaminant and adverse health effects. Adverse health effects include both noncarcinogenic and carcinogenic health effects in humans.

Carcinogenic Risks

Criteria for carcinogens are expressed as cancer slope factors (CSF) in units of risk per milligram of chemical exposure per kilogram of body weight per day. These factors are based on the assumption that no threshold for carcinogenic effects exist at any dose.

Carcinogenic risks are estimated by multiplying the chronic daily intake (CDI) for an individual by the cancer slope factor as follows:

Cancer Risk = CDI (mg/kg-day) x CSF $(\text{mg/kg-day})^{-1}$

The calculated risk is an estimate of the increased likelihood of cancer over existing levels resulting from exposure to the metal. The U.S. EPA considers a cumulative carcinogenic site risk to an individual based on reasonable maximum exposure of less than 1×10^{-6} to 1×10^{4} as acceptable (U. S. EPA, 1991). Of the metals evaluated in this risk assessment, arsenic and lead are classified by EPA as carcinogens. Toxicity values are not, however, currently available for lead, therefore, lead has been evaluated individually in Section 3.7. Arsenic is classified as a carcinogen via ingestion as well as inhalation. Table 3-16 presents the cancer slope factor for arsenic.

TABLE 3-17
SUMMARY OF CARCINOGENIC AND NONCARCINOGENIC RISKS
FOR RICO COMMUNITY SOILS

EXPOSURE AREA	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	NONCANCER RISK DUE TO MANGANESE (HQ) [2]	TOTAL NONCANCER RISK (HI) [3]
North Rico (Background)	5.31E-06	1.06E-01	9.01E-02	1.96E-01
South Rico (Background)	9.58E-06	1.92E-01	6.43E-02	2.56E-01
North Rico Residential	8.94E-06	1.79E-01	6.70E-02	2.46E-01
South Rico Residential	7.36E-06	1.48E-01	6.47E-02	2.13E-01
East Rico Future Residential	6.53E-06	1.31E-01	8.28E-02	2.14E-01
West Rico Future Residential	8.94E-06	1.79E-01	4.73E-02	2.26E-01
Silver Creek Alluvium Residential	7.30E-06	1.47E-01	8.66E-02	2.33E-01
Grand View Smelter Future Residential	1.62E-05	3.26E-01	1.36E-01	4.62E-01
Dolores River Corridor	6.92E-06	3.68E-02	2.42E-02	6.10E-02
Waste Rock Areas	6.89E-06	4.40E-02	4.09E-02	8.49E-02
Roadfill Areas	3.56E-06	2.28E-03	1.18E-03	3.46E-03

HQ = Hazard Quotient
HI = Hazard Index
(1) EPA Acceptable Risk Range: 10^{-4} - 10^{-6}
(2) EPA Acceptable NonCancer Risk: HQ < 1.0
(3) EPA Acceptable Level: HI < 1.0

TABLE 3-18
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR NORTH RICO RESIDENTIAL EXPOSURE AREA RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC (1)	NONCANCER RISK DUE TO ARSENIC (HQ) (2)	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) (2)
North Rico - Residential	34.4	8.94E-06	1.79E-01	2,552	6.70E-02

HQ = Hazard Quotient

(1) EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

(2) EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-19
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR NORTH RICO RESIDENTIAL EXPOSURE AREA (BACKGROUND) RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
North Rico - Background	20.1	5.31E-06	1.06E-01	3,616	9.01E-02

HQ = Hazard Quotient

[1] EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

[2] EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-15
EXPOSURE PARAMETERS FOR EXPOSURE SCENARIOS AT RICO

Symbol	Parameter	Residential	Recreational	Dirt Bike Rider	Units	Reference
AT	Averaging Time	Carcinogens = 25,550 Noncarcinogens = Adult: 8,760; Child: 2,190	Carcinogens = 25,550 Noncarcinogens = Adult: 8,760; Child: 2,190	Carcinogens = 25,550 Noncarcinogens: Adult: 8,760	days days	EPA, 1989a EPA, 1989a
BW	Body Weight	Adult = 70; Child = 15	Adult = 70; Child = 15	Adult = 70	kg	EPA 1989a
EF	Exposure Frequency	350 (dust) 256 (soil)	 72 (soil)	 72 (soil)	days days	EPA 1989a Site-specific
ED	Exposure Duration	Child = 6 Adult = 24	Child = 6 Adult = 24	 Adult = 30	years years	EPA 1993a EPA 1993a
ET	Exposure Time	NA	NA	5	hours	Site-specific
IR_s	Ingestion Rate (soil)	Child = 200 Adult = 100	Child = 200 Adult = 100	 Adult = 100	mg/day mg/day	EPA 1993a EPA 1993a
FS	Fraction of Soil Ingested	0.45	0.45	0.45	unitless	CDM 1995
FD	Fraction of Dust Ingested	0.55	0.55	0.55	unitless	CDM 1995
CF	Conversion Factor	0.000001	0.000001	0.000001	kg/mg	EPA 1989a
BAF_s	Bioavailability of Soil	0.183	0.183	0.183	unitless	EPA 1995a
BAF_D	Bioavailability of Dust	0.258	0.258	0.258	unitless	EPA 1995a
CSF_i	Arsenic Cancer Slope Factor for Inhalation	15	15	15	$(mg/kg\text{-}day)^{-1}$	EPA 1996
CSF_o	Arsenic Cancer Slope Factor for Ingestion	1.5	1.5	1.5	$(mg/kg\text{-}day)^{-1}$	EPA 1996
RfD	Oral reference dose for manganse	0.14	0.14	0.14	(mg/kg-day)	EPA 1996
IR	Inhalation Rate	NA	NA	2.5	m^3/day	EPA 1989b
DL	Dust Loading Factor	NA	NA	3.8×10^{-7}	kg/m^3	CDM, 1995 Life Systems, 1993

NA = Not applicable.

TABLE 3-16
TOXICITY VALUES FOR CONSTITUENTS OF CONCERN
RICO COMMUNITY SOILS

Compound	EPA Classification[1]	Cancer Slope Factor (mg/kg/day)	Oral Reference Dose (mg/kg/day)	Critical Effect/Comments	Confidence in Oral RfD	Source
Arsenic	A	1.5 (oral); 15 (inhalation)	3.00E-4	Hyperpigmentation, keratosis, possible vascular complications	Medium	IRIS
Lead	B2	NA	NA	CNS effects	NA	NA
Manganese	D	NA	1.40E-1	CNS effects	Medium	IRIS

[1]EPA Classification: A = Human carcinogen; B1 = Probable human carcinogen, B2 = Probable human carcinogen based on animal data;

C = Possible human carcinogen; D = Not classifiable as to human carcinogenicity.

NA = Not applicable.

IRIS = Integrated Risk Information System (EPA 1996)

Noncarcinogenic Risks

The reference dose (RfD) for a chemical is an estimate of the daily exposure to a chemical that would be without adverse effects even if the exposure occurs continuously over a lifetime. To estimate noncarcinogenic effects associated with exposure to a metal, the chronic daily intake (CDI) of the metal is divided by the RfD. The resultant number is termed the hazard quotient (HQ). EPA recognizes HQs less than one as acceptable. The equation for calculation of the HQ is as follows:

Hazard Quotient = CDI (mg/kg-day)/Reference Dose (mg/kg-day)

Of the metals evaluated in this risk assessment, manganese and arsenic are classified as noncarcinogens. The RfDs for arsenic and manganese are presented in Table 3-16.

If more than one noncarcinogenic chemical is present, one must add the HQs to assess the potential effects posed by exposure to multiple chemicals. This number is called the Hazard Index. If the HI exceeds 1, there may be a potential for adverse health effects from exposure to all of the chemicals at the site. Hazard quotients were calculated for exposure to arsenic and manganese at this site.

For the metals quantitatively evaluated in this risk assessment, a brief toxicity profile is provided in Appendix E.

Table 3-17 summarizes the results of the carcinogenic and non-carcinogenic risk analyses. Carcinogenic and noncarcinogenic risks for each exposure area are described in the following sections.

3.6.1 Risks Due to Arsenic and Manganese

3.6.1.1 North Rico Residential Exposures

Table 3-18 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil concentrations in the North Rico Residential Exposure Area. Arsenic cancer risk due to soil and dust ingestion (8.9E-06) is within EPA's acceptable risk range of 1.0E-04 to 1.0E-06. Manganese and arsenic noncancer risks due to soil and dust ingestion (HQ = 0.067 and 0.18, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.2 North Rico Background Residential Exposures

Table 3-19 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels based on samples representative of North Rico

TABLE 3-17
SUMMARY OF CARCINOGENIC AND NONCARCINOGENIC RISKS FOR RICO COMMUNITY SOILS

EXPOSURE AREA	CANCER RISK DUE TO ARSENIC (1)	NONCANCER RISK DUE TO ARSENIC (HQ) (2)	NONCANCER RISK DUE TO MANGANESE (HQ) (2)	TOTAL NONCANCER RISK (HI) (3)
North Rico (Background)	5.31E-06	1.06E-01	9.01E-02	1.96E-01
South Rico (Background)	9.58E-06	1.92E-01	6.43E-02	2.56E-01
North Rico Residential	8.94E-06	1.79E-01	6.70E-02	2.46E-01
South Rico Residential	7.36E-06	1.48E-01	6.47E-02	2.13E-01
East Rico Future Residential	6.53E-06	1.31E-01	8.28E-02	2.14E-01
West Rico Future Residential	8.94E-06	1.79E-01	4.73E-02	2.26E-01
Silver Creek Alluvium Residential	7.30E-06	1.47E-01	8.66E-02	2.33E-01
Grand View Smelter Future Residential	1.62E-05	3.26E-01	1.36E-01	4.62E-01
Dolores River Corridor	6.92E-06	3.68E-02	2.42E-02	6.10E-02
Waste Rock Areas	6.89E-06	4.40E-02	4.09E-02	8.49E-02
Roadfill Areas	3.56E-06	2.28E-03	1.18E-03	3.46E-03

HQ = Hazard Quotient
HI = Hazard Index
(1) EPA Acceptable Risk Range: 10^{-4} - 10^{-6}
(2) EPA Acceptable NonCancer Risk: HQ < 1.0
(3) EPA Acceptable Level: HI < 1.0

TABLE 3-18
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR NORTH RICO RESIDENTIAL EXPOSURE AREA RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
North Rico - Residential	34.4	8.94E-06	1.79E-01	2,552	6.70E-02

HQ = Hazard Quotient

[1] EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

[2] EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-19
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR NORTH RICO RESIDENTIAL EXPOSURE AREA (BACKGROUND) RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC (1)	NONCANCER RISK DUE TO ARSENIC (HQ) (2)	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) (2)
North Rico - Background	20.1	5.31E-06	1.06E-01	3,616	9.01E-02

HQ = Hazard Quotient

(1) EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

(2) EPA Acceptable NonCancer Risk: HQ < 1.0

Background. Arsenic cancer risk due to soil ingestion (5.3E-06) is within EPA's acceptable risk range of 1.0E-04 to 1.0E-06. Manganese and arsenic noncancer risks due to soil and dust ingestion (HQ = 0.09 and 0.11, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.3 South Rico Residential Exposures

Table 3-20 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels in South Rico Residential Exposure Area. Arsenic cancer risk due to soil and dust ingestion (7.3E-06) is within EPA's acceptable risk range of 1.0E-04 to 1.0E-06. Manganese and arsenic noncancer risks due to soil and dust ingestion (HQ = 0.065 and 0.15, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.4 South Rico Background Exposures

Table 3-21 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels for samples representative of South Rico Background. Arsenic cancer risk due to soil and dust ingestion (9.6E-06) is within EPA's acceptable risk range of 1.0E-04 to 1.0E-06. Manganese and arsenic noncancer risks (HQ = 0.064 and 0.19, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.5 East Rico Future Residential Exposures

Table 3-22 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels in the East Rico Residential Exposure Area. Arsenic cancer risk due to soil and dust ingestion (6.5E-06) is within EPA's acceptable risk range of 1.0 E-04 to 1.0E-06. Manganese and arsenic noncancer risks (HQ = 0.082 and 0.13, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.6 West Rico Future Residential Exposures

Table 3-23 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels in the West Rico Residential Exposure Area. Arsenic cancer risk due to soil and dust ingestion (8.9E-06) is within EPA's acceptable risk range of 1.0 E-04 to 1.0E-06. Manganese and arsenic noncancer risks (HQ = 0.047 and 0.18, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.7 Silver Creek Alluvial Fan - Residential Exposures

Table 3-24 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels in the Silver Creek Alluvial Fan Exposure Area. Arsenic cancer risk due to soil and dust ingestion (7.3E-06) is within EPA's acceptable risk range

TABLE 3-20
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR SOUTH RICO RESIDENTIAL EXPOSURE AREA RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
South Rico - Residential	28.5	7.36E-06	1.48E-01	2,508	6.47E-02

HQ = Hazard Quotient

[1] EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

[2] EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-21
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR SOUTH RICO RESIDENTIAL EXPOSURE AREA (BACKGROUND) RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
South Rico - Background	43	9.58E-06	1.92E-01	2,536	6.43E-02

HQ = Hazard Quotient

(1) EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

(2) EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-22
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR EAST RICO FUTURE RESIDENTIAL EXPOSURE AREA RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
East Rico - Future Residential	25.2	6.53E-06	1.31E-01	3,469	8.28E-02

HQ = Hazard Quotient

[1] EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

[2] EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-23
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR WEST RICO FUTURE RESIDENTIAL EXPOSURE AREA RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
West Rico - Future Residential	33	8.94E-06	1.79E-01	1,810	4.73E-02

HQ = Hazard Quotient
[1] EPA Acceptable Risk Range: 10^{-4} - 10^{-6}
[2] EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-24
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR SILVER CREEK ALLUVIUM RESIDENTIAL EXPOSURE AREA
RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
Silver Creek Alluvium - Residential	35	7.30E-06	1.47E-01	3,516	8.66E-02

HQ = Hazard Quotient

[1] EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

[2] EPA Acceptable NonCancer Risk: HQ < 1.0

of 1.0E-04 to 1.0E-06. Manganese and arsenic noncancer risks (HQ = 0.086 and 0.15, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.8 Grand View Smelter Data - Future Residential Exposures

Table 3-25 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM concentrations for the Grand View Smelter site. Cancer risks due to soil and dust ingestion of arsenic (1.6E-05) is within EPA's acceptable risk range of 1.0E-04 to 1.0E-06. Noncarcinogenic risks due to ingestion of manganese and arsenic (HQ = 0.14 and 0.33, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.9 River Corridor (Recreational) Exposures

Table 3-26 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels in the River Corridor (recreational) Exposure Area. Arsenic cancer risks due to soil ingestion (6.9E-06) is within EPA's acceptable risk range of 1.0E-04 to 1.0E-06. Manganese and arsenic noncancer risks (HQ = 0.024 and 0.037, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.10 Waste Rock Areas - Recreational Exposures

Table 3-27 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels in the waste rock areas in Rico. Arsenic cancer risk due to soil ingestion (6.9E-06) is within EPA's acceptable risk range of 1.0E-04 to 1.0E-06. Manganese and arsenic noncancer risks (HQ = 0.041 and 0.044, respectively) are less than EPA's acceptable level of 1.0.

3.6.1.11 Road Fill (Dirt Bike) Exposure Scenario

Table 3-28 summarizes carcinogenic risks for arsenic and noncarcinogenic risks for arsenic and manganese based on 95% UCLM soil levels in the road fill. Arsenic cancer risks due to soil ingestion and dust inhalation by a dirt bike rider (3.5E-06) is within EPA's acceptable risk range of 1.0E-04 to 1.0E-06. Manganese and arsenic noncancer risks (HQ = 0.0012 and 0.0023, respectively) are less than EPA's acceptable level of 1.0.

3.7 Risk Assessment for Residential Lead Exposures

Due to the lack of toxicity values for lead, health risks due to lead exposure cannot be evaluated using traditional risk assessment approaches. Therefore, health risks due to exposure to lead have been evaluated using the results of scientific studies at mining sites.

TABLE 3-25
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR GRAND VIEW SMELTER FUTURE RESIDENTIAL EXPOSURE AREA RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
Grand View Smelter - Future Residential	71	1.62E-05	3.26E-01	10,120	1.36E-01

HQ = Hazard Quotient

[1] EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

[2] EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-26
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR RECREATIONAL VISITORS TO THE RIVER CORRIDOR
RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC [1]	NONCANCER RISK DUE TO ARSENIC (HQ) [2]	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) [2]
River Corridor	45.7	6.92E-06	3.68E-02	5,162	2.42E-02

HQ = Hazard Quotient

[1] EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

[2] EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-27
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR RECREATIONAL VISITORS TO THE WASTE ROCK AREAS
RICO COMMUNITY SOILS

EXPOSURE AREAS	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC (1)	NONCANCER RISK DUE TO ARSENIC (HQ) (2)	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) (2)
Waste Rock Areas	55	6.89E-06	4.40E-02	8,739	4.09E-02

HQ = Hazard Quotient
(1) EPA Acceptable Risk Range: 10^{-4} - 10^{-6}
(2) EPA Acceptable NonCancer Risk: HQ < 1.0

TABLE 3-28
SUMMARY OF ARSENIC AND MANGANESE RISKS FOR DIRT BIKE RIDERS BASED ON ROADFILL DATA
RICO COMMUNITY SOILS

EXPOSURE AREA	ARSENIC 95% UCLM (mg/kg)	CANCER RISK DUE TO ARSENIC (1)	NONCANCER RISK DUE TO ARSENIC (HQ) (2)	MANGANESE 95% UCLM (mg/kg)	NONCANCER RISK DUE TO MANGANESE (HQ) (2)
Roadfill Areas	30	3.56E-06	2.28E-03	2,596	1.18E-03

HQ = Hazard Quotient

(1) EPA Acceptable Risk Range: 10^{-4} - 10^{-6}

(2) EPA Acceptable NonCancer Risk: HQ < 1.0

3.7.1 Exposure Studies

The most reliable indicator of exposure and risk in a population is an environmental health/blood lead study that collects information on lead concentrations in environmental and biological samples. Such studies provide useful data on the relationship between blood lead levels and environmental factors that impact blood lead levels. Therefore, blood lead measurements are a commonly used and widely accepted indicator of lead exposures (CDC, 1991; U.S. EPA, 1986) and are " considered to be the most useful and practical monitor of exposure" (ATSDR, 1988). In addition, blood lead measurements are recognized as being a reliable index of both lead exposures and relative risk for various adverse health effects (ATSDR, 1988).

3.7.2 CDC/EPA Action Levels

Because some adverse health effects have been documented at least as low as 10 micrograms per deciliter (μg/dl), both CDC and EPA have adopted 10 μg/dl as a blood lead level of concern. Furthermore, it is CDC's goal that lead poisoning prevention activities be geared towards reducing children's blood lead levels to below 10 μg/dl. Table 3-29 provides a summary of blood lead levels and corresponding recommended remedial actions (CDC, 1991). It should be noted that CDC recommends remediation at blood lead levels greater than 20 μg/dl.

3.7.3 Exposure Studies at Mining Sites

Although, there are no blood lead study data available for the Rico Community, there are numerous blood lead studies that have been conducted over the last 10 years in mining communities with similar ranges of soil lead concentrations and lead mineralogy to Rico. The results of these studies, conducted by independent researchers in cooperation with federal/state public health agencies, provide a sound basis to assess likely lead risks in the Rico Community.

The following provides a summary of blood lead studies conducted in mining communities:

3.7.3.1 Aspen, Colorado

This study was conducted by the ATSDR and the Colorado Department of Health (CDH) in 1990 (ATSDR, 1992). The geometric mean blood lead level for children less than six (6) years of age who resided near the Smuggler Mountain mine site was 2.6 μg/dl. This level was well below the CDC/EPA 10 μg/dl level of concern and below the 4.5-5.5 μg/dl national background level estimated by EPA for children not exposed to a specific source of lead in the environment (U.S. EPA, 1989c). Soil lead concentrations in yards of the children ranged from 135 to 11,676 mg/kg (geomean value was 641 mg/kg). ATSDR and CDH concluded that there was no association between lead-containing mining wastes in soil and children blood lead levels.

TABLE 3-29
Interpretation of Blood Lead Test Results and Follow-up Activities

Blood Lead Concentration (µg/dL)	Comment
< or = 9	A child is not considered to be lead-poisoned.
10 - 14	Many Children (or a large proportion of children) with blood lead levels in this range should trigger community-wide childhood lead poisoning prevention activities. Children in this range may need to be rescreened more frequently.
15 - 19	A child should receive nutritional and educational interventions and more frequent screening. If the blood lead level persists in this range, environmental investigation and intervention should be done.
20 - 44	A child should receive environmental evaluation and remediation and a medical evaluation.

Reference:
U.S. Department of Health and Human Services, Centers for Disease Control, 1991, "Preventing Lead Poisoning in Young Children", October.

3.7.3.2 Butte, Montana

This study was conducted by the Butte-Silver Bow Health Department and University of Cincinnati in 1990 (Butte-Silver Bow, 1992). The study was designed to reflect worst-case risks in Butte, because the majority of children tested resided in areas where soil lead levels were the highest. The geometric mean blood lead level for children less than six (6) years old who resided in close proximity to mine waste areas was 3.5 μg/dl. This level was well below the CDC/EPA 10 μg/dl level of concern and below the 4.5-5.5 μg/dl national background level estimated by EPA for children not exposed to a specific source of lead in the environment (U. S. EPA, 1989c). Soil lead concentrations in yards of the children ranged from 28 to 8,411 mg/kg. Table 3-30 shows the impact of soil lead greater than 2,500 ppm on blood lead levels. Children who lived at residences with soil lead ranging from 2,500 to 8,500 mg/kg (which is about 6 times higher than the average soil level in Butte) had approximately the same average blood lead levels (3.8 μg/dl) as those exposed to lower soil lead levels (4.2 μg/dl). The study researchers concluded that there was no direct relationship between soil lead and children's blood lead levels, and therefore mining wastes in Butte did not represent a human health risk.

3.7.3.3 Bingham Creek, Utah

This study was conducted by the Salt Lake City-County Health Department and the University of Cincinnati in the late summer and fall of 1993 among children who resided in close proximity to the Bingham Creek Channel (U.S. EPA 1995d). The geometric mean blood lead level for children less than six (6) years old was 2.6 μg/dl. This level was well below the CDC/EPA 10 μg/dl level of concern and below the 3.6 μg/dl national background level estimated in the recent national (National Health and Nutrition Examination Surveys (NHANES III)) blood lead survey for children less than 5 years old not exposed to a specific source of lead in the environment (Pirkle et. al., 1994). Soil lead levels in the yards of the children ranged from 9 to 2,291 mg/kg. The study researchers could not demonstrate any direct impact of soil containing mining waste lead on blood lead levels.

3.7.3.4 Leadville, Colorado

This study was conducted by the Lake County Health Department and the University of Cincinnati in 1991 (U.S. EPA, 1995c). The geometric mean blood lead level of children less than six (6) years of age who resided in close proximity to mining waste areas was 4.8 μg/dl. This level was below the CDC/EPA 10 μg/dl level of concern and within the 4.5 to 5.5 μg/dl national background level estimated by EPA for children not exposed to a specific source of lead in the environment (U.S. EPA, 1989c). Soil concentrations in yards of the children ranged from 43 to 24, 099 mg/kg (geometric mean concentration was 915 mg/kg). The study researchers concluded that there was no direct impact of soils containing lead from mining wastes and blood lead levels. Follow-up studies in 1992, 1993 and 1994 show that blood lead levels are continuing to fall even though no soil remediation has occurred (Bornschein, personal communication, 1996).

TABLE 3-30
Impact of Soil Lead Greater Than 2500 ppm on Children's Blood Lead

ID Number	Soil Lead (ppm)	Blood Lead Aug. 1990 µg/dL
A3286	8411	5.5
A3132	4272	6.5
A3428	3991	6.5
A3340	3642	3.5
A0755	3387	7.5
A0769	3243	2.0
A0769	3243	2.5
A2145	3165	3.5
A0801	2773	3.0
A0801	2773	4.0
A3425	2763	3.0
A1187	2714	1.0
G0388	2612	3.5
A3379	2558	2.5

Reference:

Department of Environmental Health, University of Cincinnati, 1992, "The Butte-Silver Bow County Environmental Health Lead Study Final Report. February.

3.7.3.5 Telluride, Colorado

This study was conducted by the University of Cincinnati for the Idarado Mining Company in 1986 (Bornschein, et al., 1988). The geometric mean blood level of children less than six (6) years of age, who resided in close proximity to mining waste areas, was 6.1 μg/dl. This level was below the CDC/EPA 10 μg/dl level of concern and below the U.S. Department of Human Health Services projected national background levels of 8.0 to 9.7 μg/dl for children not exposed to a specific source of lead in the environment (U.S. Department of Health and Human Services, 1984). Soil lead concentrations in residential yards ranged from 17 to 804 mg/kg. The study researchers concluded that lead in soil did not directly contribute to the children's blood lead levels.

3.7.3.6 Midvale, Utah

This study was conducted by the University of Cincinnati for Sharon Steel and others in 1989 (University of Cincinnati, 1990). The geometric blood lead level of children less than six (6) years of age who resided in close proximity to mining waste areas, was 5.2 μg/dl. This level was below, the CDC/EPA 10 μg/dl level of concern and below the U.S. Department of Human Health Services projected national background levels of 8.0 to 9.7 μg/dl for children not exposed to a specific source of lead in the environment. Soil lead concentrations in residential yards ranged from 58 to 1,989 mg/kg (geomean level was 342 mg/kg). The study researchers could not detect any direct relationship between soil lead levels and children's blood lead levels.

3.7.3.7 Summary of Mining Studies

Table 3-31 provides a comparison of the type of mining activity, mineralogy and range of residential soil lead levels in Rico to the soil lead/blood lead levels in the six mining communities discussed above. Combined, these studies represent the results from over 1,800 children. As shown in the table, geometric blood lead levels were below the EPA/CDC 10 μg/dl blood lead level of concern. In addition, blood lead levels were below background blood lead levels estimated by public health agencies for the year in which the blood lead study was conducted.

Danse, et. al. (1995), assessed the impact of mining wastes on blood lead levels by comparing blood lead levels from individuals and environmental lead from soils impacted from mining in 13 communities in the U.S. (Telluride, Butte, Midvale and Aspen included), Australia and the United Kingdom. Almost 3,000 blood lead measurements were available from individuals residing on or near mining wastes. The researchers concluded that blood lead levels in children were comparable to controls and were below NHANES and EPA projections for background (general population) blood lead levels.

Based on the review of blood lead exposure studies in similar communities to Rico, it is very unlikely that elevated blood lead levels would be found in residents exposed to background

TABLE 3-29
Interpretation of Blood Lead Test Results and Follow-up Activities

Blood Lead Concentration (µg/dL)	Comment
< or = 9	A child is not considered to be lead-poisoned.
10 - 14	Many Children (or a large proportion of children) with blood lead levels in this range should trigger community-wide childhood lead poisoning prevention activities. Children in this range may need to be rescreened more frequently.
15 - 19	A child should receive nutritional and educational interventions and more frequent screening. If the blood lead level persists in this range, environmental investigation and intervention should be done.
20 - 44	A child should receive environmental evaluation and remediation and a medical evaluation.

Reference:
U.S. Department of Health and Human Services, Centers for Disease Control, 1991, "Preventing Lead Poisoning in Young Children", October.

soil lead concentrations or lead concentrations in soils in existing residential areas in north and south Rico and in the future residential areas in the east and west portions of the community.

Review of lead bioavailability studies (Freeman et al., 1992; Davis et al., 1993; Ruby et al., 1992; and Davis et al., 1991) indicate that lead from mining wastes are not readily absorbed in the body. These studies as well as other research in this area indicate that lead bearing mining wastes do not dissolve rapidly or completely when ingested and, therefore, are less bioavailable than other more soluble forms of lead found in the environment. The bioavailability of lead in mining wastes has been estimated to be low due to the following four factors: 1) type of lead - lead compounds found in mining waste are less soluble in the GI tract; 2) encapsulation - much of lead in mining wastes is trapped inside other minerals such as quartz that prevent the lead compounds from dissolving; 3) rinding - this process occurs when minerals form on the surface of a particle due to alteration or precipitation, the coating prevents the particle from dissolving and 4) rate of dissolution in the GI tract - because the lead particles are encapsulated or covered with rinds, they may dissolve very slowly.

The results of the mineralogical analysis of lead-bearing minerals in bedrock, disturbed and undisturbed and disturbed colluvium, alluvium and talus slope areas at Rico indicate that the mineral form of lead at Rico is comparable to that found in other mining communities with low blood lead levels (see Table 3-31; Geomega, 1996).

3.7.3 Risk Assessment for Recreational Exposures to Lead

Comparison of soil lead concentrations in the River Corridor and waste rock areas to recreational lead clean-up levels at similar sites indicates that soil lead concentrations in the River Corridor and waste rock areas are below recommended lead screening levels. For example, the human health risk assessment for the Leadville Colorado mining site, cites a preliminary cleanup goal (PRG) for lead of 16,700 mg/kg for recreational exposures (U.S. EPA 1995c). The UCLM for lead in the River Corridor is 4,300 mg/kg. These values are well below the PRG of 16,700 mg/kg recommended for recreational exposures at Leadville. The UCLM for lead in the waste rock areas is 15,300 mg/kg. Soil lead concentrations in the waste rock areas are below the PRG of 16,700 mg/kg cited for Leadville.

3.7.4 Grand View Smelter

Table 3-8 indicates that from the three samples obtained at the Grand View smelter site, soil lead concentrations ranged from 3,460 mg/kg to 6,290 mg/kg from which a UCLM of 7,240 mg/kg was calculated. The results of the mineralogical analysis of lead-bearing wastes at the site, described in Section 2.5.6.5, indicates that the smelter wastes are predominantly complex assemblages of ore and refractory minerals, cinders, ash and slag; materials which are not similar to the lead-bearing, non-processed bedrock and surficial

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materials (mine waste rock and mill tailings included) distributed throughout the Rico area. Potential lead risks associated with these smelter wastes cannot be adequately addressed without further mineralogical and bioavailability studies which are not available at this time.

3.8 Uncertainties Associated with the Health Risk Assessment

For all risk assessment efforts, there is a level of uncertainty associated with the risk estimate that must be considered. Uncertainty reflects the degree to which an analysis may be incorrect. This section describes some uncertainties associated with the risk analysis for exposure to metals within the Rico Mining District.

Uncertainties Associated with the Bioavailability of Arsenic

The bioavailability factors recommended by EPA for use in risk assessments are typically based on studies using soluble metal salts. These values are inappropriate for use at a mining site, as arsenic and lead in solid phases of soil are typically much less soluble than metal salts. The bioavailability of arsenic has recently been investigated (Freeman, et al. 1995). This study indicated that absorption of arsenic from soils and dust is significantly less than absorption of soluble arsenic from water. The study titled "Determination of the Bioavailability of Soluble Arsenic and Arsenic in Soil and Dust Impacted by Smelter Activities Following Oral Administration in Cynomolgus Monkeys", presented blood arsenic, urine arsenic and fecal arsenic data collected from Cynomolgus monkeys exposed to arsenic by intravenous injection, oral gavage and capsules containing soil and dust.

The absolute bioavailability estimated from blood arsenic concentrations ranged between 91 and 100 percent for oral gavage, 11 and 18 percent for soil ingestion and 8 and 11 percent for dust. Based on the study results, the EPA derived arsenic bioavailability estimates for ingested soil and dust (U.S. EPA 1994b, 1995b). The bioavailability value selected for dust absorption was 25.8 percent and for soil absorption was 18.3 percent. Due to the ranges of bioavailability, the exposure to arsenic may be slightly overestimated in the HRA as the upper end of each range was used for the BAF.

Uncertainties Associated with Toxicity Values

Reference doses are estimated with uncertainty factors. Uncertainty factors may range from 1 to 10 and are applied for the following reasons: 1) extrapolation from a lowest observed adverse effect level (LOAEL) to a no-observed adverse effect level (NOAEL), if a NOAEL was not established in the study; (2) extrapolation from a subchronic exposure to chronic exposure if the study was not chronic; (3) extrapolation of animal data to human data if the study was not in humans; and (4) extrapolation from an average human population to a sensitive subpopulation. An additional modifying factor may be applied if an incomplete data set was used to develop the reference dose (RfD) or reference concentration (RfC). The oral reference dose for arsenic has an uncertainty factor of 3 to account for the lack of data to preclude reproductive toxicity as a critical effect and to account for some uncertainty in whether the NOAEL of the critical study accounts for all sensitive individuals.

The oral cancer slope factor for arsenic has recently been debated by many investigators in the field of public health. Many believe that the oral CSF for arsenic is too high and that the Taiwanese population (Tseng, 1977) from which the toxicity value is based is inappropriately used. The Tseng study found that among individual studies, those that drank well water contaminated from high levels of arsenic, had an increased incidence of skin cancer. A recent study by Yost et al. (1994) indicates that estimates of inorganic arsenic in the diet of the Taiwanese population may have been underestimated in the study. The underestimation of arsenic concentrations would result in an exaggerated estimate of cancer potency. In addition, the current Taiwanese data does not allow a conclusion to be drawn regarding the existence of a threshold for arsenic's carcinogenicity. In November 1993, the Science Advisory Board (SAB) recommended that EPA clarify dose-response and pharmacokinetics relationships for arsenic in humans. The SAB also stated that the EPA did not adequately consider available information about the metabolism and detoxification mechanisms of arsenic. The SAB concluded that "...available data suggest that arsenic blood concentrations may only become elevated when the level of arsenic in water exceeds 100 μg/L....". The SAB concluded that this is a critical question because the excess risks in the Taiwanese studies are the primary evidence for quantitative risk assessment, and risks in those studies have only been observed at arsenic water levels that are well in excess of this figure.

Other uncertainties associated with derivation of the cancer potency factor for arsenic from the Taiwanese study have been identified (metabolism of arsenic, inadequate dietary methionine in the Taiwanese diet, presence of humic acids in the water supply for the Taiwanese population). These factors will not be described in detail, however, it is important to recognize the many uncertainties associated with the derivation of the cancer slope factor for arsenic from the Taiwanese study that would tend to overestimate cancer risk.

In addition, EPA has recently delayed promulgating a new maximum contaminant level (MCL) for ingested arsenic due to uncertainties (probable overestimates of toxicity) related to the cancer slope factor.

Uncertainties Associated with Exposure Estimates

Several of the exposure estimates in the risk assessment represent the high end of possible values for each parameter. EPA recommends that for exposure assessments, intake and exposure values should be selected so that the combination of variables results in an estimate of the reasonable maximum exposure (RME) for each pathway. The RME is the maximum exposure that is reasonably expected to occur at that site. The algorithms and associated parameters presented in this HRA were recommended by EPA and represent a mix of high-end and mid-range values. For example, it is assumed that an individual may live in the Rico area for 30 years. This number is based on statistics and is the national upper-bound time (90th percentile) at one residence. This value is, therefore, a conservative estimate and may overestimate risks at Rico. Likewise, the soil ingestion rate represents the 90th percentile and may also overestimate intake and risks. The exposure frequency for dust ingestion is estimated at the high end of possible estimates. The exposure frequency assumes only two weeks of vacation per year. Many individuals may spend more time than this away from home. Therefore, the exposure frequency of 350 days per year may overestimate exposures for dust ingestion at Rico. Similarly, the exposure frequency for soil ingestion was assumed to be 256 days per year. This value assumes that three months of the year the ground is either frozen or covered with snow, making exposure to soils unlikely. In addition, it was assumed that two weeks of the year are spent away from home on vacation. This exposure frequency probably overestimates exposures to soil as the ground is most likely covered with snow longer than three months per year. In addition, this value assumes that exposure to soil will occur every day. Therefore, the exposure estimate for soil ingestion is conservative and may overestimate exposures to soil. The values for life span and body weight represent 50th percentile values and most likely do not over- or under-estimate exposures at Rico.

There is a large amount of uncertainty associated with the estimate of exposures for the dirt bike rider. Several calculations were performed in order to estimate the amount of dust a dirt bike rider may inhale. Due to lack of site-specific data such as the average wind speed and the silt content of soils, data used at the Anaconda site were assumed or literature values were obtained. These estimates are, therefore, associated with a large amount of uncertainty and risks associated with the dirt bike rider scenario may be over- or under-estimated.

Finally, because very little information is available on which to base estimates of dermal absorption of arsenic or metals in soil, these estimates were not performed in the risk assessment. However, several reports indicate that dermal absorption is very inefficient, even for soluble arsenic or metal forms (ATSDR,1991). Although this data pertains to laboratory animals, and is therefore, difficult to extrapolate to human exposure, it does indicate that dermal exposure should be an insignificant pathway relative to soil ingestion and dust inhalation.

3.9 Conclusions

The following summarizes the findings and conclusions of the risk assessment.

Comparison of metals concentrations in soils at the Rico Mining District to State and EPA screening levels indicate that lead, arsenic and manganese exceed at least one of the screening levels. Soil concentrations of cadmium, copper, zinc and silver did not exceed State or EPA screening levels.

Comparison of arsenic, lead and manganese to background soil concentrations indicates that arsenic, lead and manganese concentrations in residential areas generally fall below background concentrations for these metals. In addition, t-test results indicate that arsenic, manganese and lead concentrations in residential areas are similar to background concentrations for these metals. Correlation coefficients for arsenic concentrations with lead and zinc are very low, indicating that arsenic is independently distributed. These results suggest that arsenic, lead and manganese are present in most areas of Rico at concentrations that are naturally occurring background concentrations.

Carcinogenic risks due to soil and dust ingestion of arsenic from recreational and residential exposures and inhalation of dust by dirt bike riders are within EPA's acceptable range of 1.0E-04 to 1.0E-06 for all exposure areas evaluated.

Noncarcinogenic risks due to soil ingestion of arsenic and manganese for recreational and residential exposures are less than EPA's acceptable level of 1.0.

Carcinogenic risks for exposure to arsenic and noncarcinogenic risks for expsoure to arsenic and manganese are within EPA's acceptable ranges for future residential exposures at the Grand View smelter site.

Based on review of blood lead exposure studies in similar communities to Rico, it is very unlikely that elevated blood lead levels would be found in residents exposed to background lead levels or lead concentrations in soils in existing residential areas in north and south Rico and in the future residential areas in the east and west portion of the community.

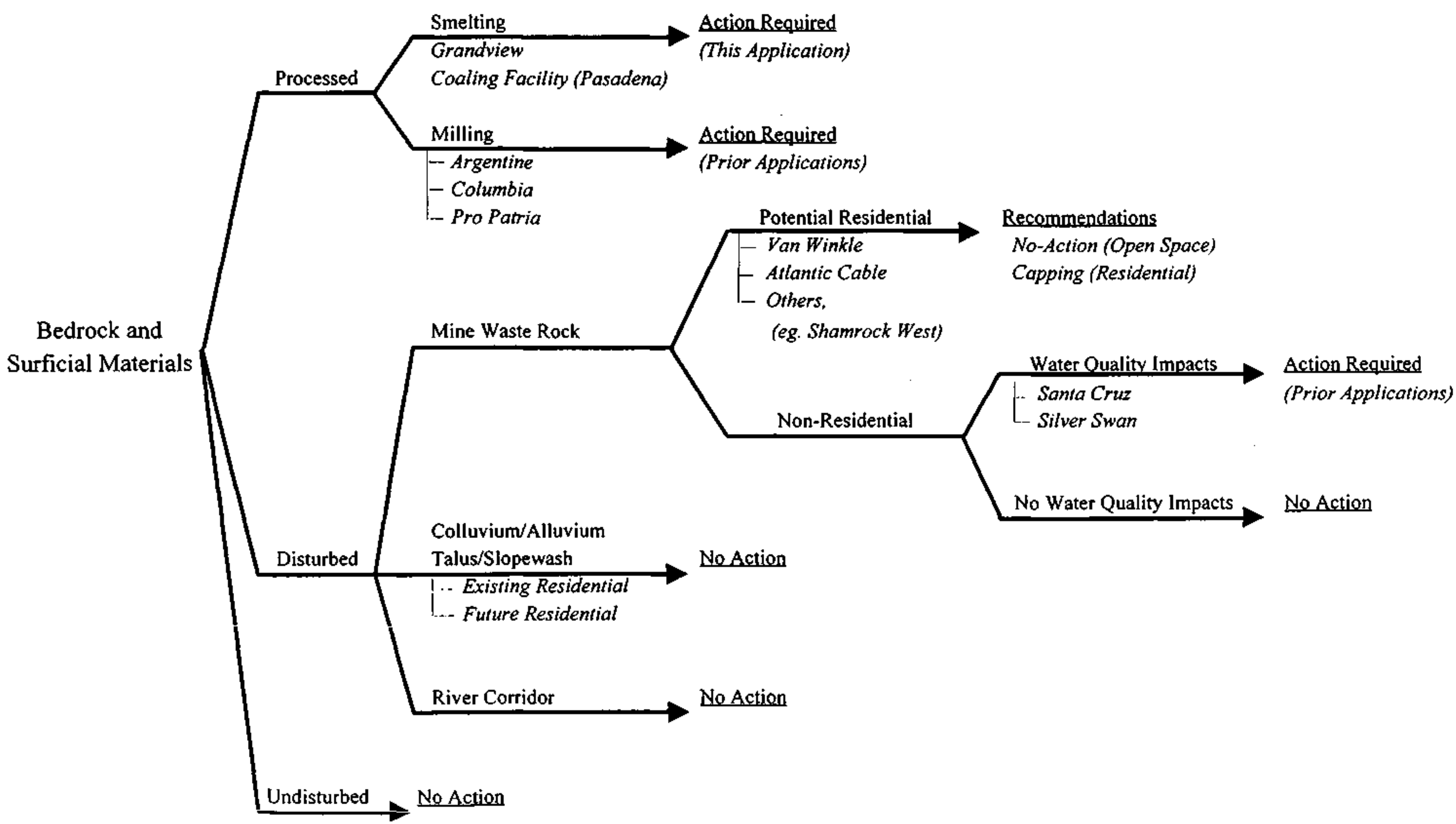
Future residential risks for lead exposure at the Grand View smelter site are uncertain because the lead-bearing phases at this site are anthropogenic in their origin and different from the natural mineral assemblages present at mining sites where health risks have been previously evaluated.

Recreational soil lead screening levels cited at similar sites (Leadville, CO) indicate that exposures to lead concentrations in the River Corridor and waste rock areas in Rico are unlikely to pose unacceptable health risks to recreational visitors.

3.10 Recommended Action at Rico

Figure 3-6 provides a comprehensive summary of the remedial decisions for the overall Rico cleanup program. These decisions result from the characterization and risk assessment related to specific materials (processed, disturbed and undisturbed) that are all ultimately derived from bedrock and surficial materials in the Rico area. As can be seen from Figure 3-6, site-specific remediation of sources of metals contained in mine waste rock and mill tailings have

Figure 3-6
Diagram Illustrating Remedial Decisions



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already been addressed under the Argentine, Columbia, Santa Cruz and Silver Swan VCUP applications. However, for this application, action is recommended at the Grand View smelter site and the RSG Coaling Facility (Pasadena smelter site) and recommendations are suggested for mine wastes such as the Van Winkle and Atlantic Cable sites based on potential future land use.

The health risk assessment conducted as part of this application was targeted mainly at the potential sources of exposure from arsenic, lead and manganese contained in naturally-occurring materials and mining wastes, i.e. waste rock and mill tailings that have not been processed to the extent that changes in mineral form have taken place. As previously discussed, the conclusions of the risk assessment support a no-action decision for the (1) existing residential areas located on bedrock, colluvium and alluvium materials; (2) future residential areas located on talus/slopewash material and (3) open-space river corridor area. **In addition, results of the risk assessment for arsenic and manganese at the Grand View smelter site indicate that both carcinogenic and non-carcinogenic risks would be within acceptable ranges for a residential scenario, a possible future use for at least part of the site.**

In summary, all quantitative cancer risk estimates fall within EPA's acceptable range of 1×10^{-6} to 1×10^{-4}. In the National Oil and Hazardous Substances Pollution Contingency Plan (the NCP), EPA established an acceptable risk range of 10^{-4} to 10^{-6}. In 1991, the EPA clarified it's position to make a risk of 10^{-4} the decision point for determining whether remediation is warranted:

> "Where the cumulative carcinogenic site risk is less than 10^{-4},...action generally is not warranted, unless there are adverse environmental impacts...Generally, where the baseline risk assessment indicates that a cumulative site risk to an individual using reasonable maximum exposure assumptions for either current or future land use exceeds the 10^{-4} lifetime excess cancer risk end of the risk range, action under CERCLA is generally warrantetd at the site" (U.S. EPA, 1991).

Risks associated with exposure to lead for future residents at the Grand View smelter site, however, are uncertain based on the processed nature and mineralogy of lead contained in the smelter waste on the property. The mineral form of the lead in the smelter wastes is, in part, different than the mineralogy of the naturally-occurring materials and mining wastes in the Rico Mining District. This is confirmed by the results of the mineralogical analysis described in Section 2.5.6.5 which concludes that the lead-bearing phases in the smelter wastes are predominantly complex assemblages of ore and refractory minerals, cinders, ash, and slag. Because these materials are anthropogenic in their origin, and not similar to the naturally-occurring (bedrock and surficial materials) and mining sources of lead in the Rico Mining District, it would not be appropriate to make the same conclusions with regards to future lead health risk based on the anticipated residential land use of the Grand View smelter site.

In order to conduct a comprehensive risk assessment of the wastes associated with historic smelting at the site, it would be necessary to conduct additional lead mineral characterization and animal bioavailability studies to determine the extent of exposure and risk that may be associated with these wastes. Rather than initiating additional lengthy studies, it is recommended that action be taken at the Grand View smelter site to eliminate any concern that may be associated with future development. The specific activities proposed for the site are discussed in Section 4.0.

In addition to the proposed action at the Grand View smelter site, action is recommended at the RGS coaling facility (former Pasadena smelter site). Please see Appendix B for a description of the proposed action for this site.

Figure 3-6 also indicates that recommendations for action be considered at the Van Winkle and Atlantic Cable sites based on potential future land use. Although risk assessment results for arsenic, manganese and lead, indicate no-action would be required for open-space (recreational) use at these sites, capping of wastes is recommended should the landowner decide to develop these sites for residential purposes.

Although, the results of the health risk assessment support a no-action decision for materials containing naturally-occurring or mining waste sources in residential and recreational areas in Rico, implementation of the recommended actions outlined above are necessary to assure protection of public health based on future land use and to complete the overall Rico cleanup program.

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4.0 VOLUNTARY CLEANUP PLAN

"The voluntary cleanup plan must address known or potential releases of contaminants considering the human health and environmental risks of those contaminants in both the present and future land use scenarios. The plan must demonstrate that either all applicable state standards will be met, or for contaminants where no standard exists, that the risk level has been reduced to an acceptable level (excess cancer risk of 10^{-6}, or hazard index < 1).

The remediation alternative selected should be described in sufficient detail to allow the Department to evaluate whether or not the applicant will be capable of remediating all contamination identified at the subject property within the specified 24 month time limit set down in 25-16-306(4)(a)."

4.1 Introduction

The primary objectives of this Voluntary Cleanup Plan (VCUP) for the Grand View smelter site ("Site") are to:

- Effectively minimize the potential for direct human health exposure to the smelter waste; and

- Stabilize the Site against erosion from runon/runoff to prevent off-site dispersal of wastes.

These objectives address the known or potential releases of contaminants at the Site, as described and discussed in the environmental assessment (Section 2.0) and the applicable standards/risk determination (Section 3.0).

The design bases and proposed remedial design for the Site are described in Section 4.2. The design bases include best management practices (BMPs) and standard engineering practice. The remediation techniques encompass hydrologic controls and reclamation cover. Specific Site remediation measures to be implemented involve:

- Construction of drainage control structures (e.g., access road drainage ditch, culvert, erosion protection) to provide controlled runon/runoff of upland water and direct precipitation;

- Placement of growth media, mulching, and revegetating bare slopes and exposed waste material to minimize human and environmental exposure, and to minimize erosion.

Other aspects of the VCUP are described in Sections 4.3 through 4.8. These are summarized briefly as follows:

- Short- and long-term risks associated with the implementation (construction) and operation of the VCUP are relatively low and fully manageable; all of the proposed remediation measures are technically feasible;

- Operations and maintenance (O&M) requirements have been specifically minimized to the extent practicable as part of the conceptual design, and are simple and fully implementable;

- Discussions regarding permit or other approval mechanisms for measures under the VCUP are currently being pursued with federal and state agencies. Any permit requirements will be structured to support the remedial nature of the proposed activities and are expected to dovetail with VCUP components described herein.

- The proposed plan can be implemented within the required 24-month time frame, assuming timely reviews and permit approvals, and barring extreme weather conditions.

4.2 Grand View Smelter Site Remedial Design

The VCUP should include: *"A detailed description of the remediation alternative, or alternatives selected, which will be used to remove, or stabilize contamination released into the environment, or threatened to be released into the environment;*

A map identifying areas to be remediated, the area where the remediation system will be located, if it differs from the contaminated areas, locations of confirmation samples, the locations of monitoring wells, areas where contaminated media will temporarily be stored/staged, and areas where contamination will not be remediated; and

Remediation system design diagrams showing how the system will be constructed in the field."

4.2.1 Introduction

The conceptual plan for remediation of the Site is described in the following subsections. The proposed remediation measures to be implemented are described in sufficient detail to document that the concepts are technically and economically feasible, constructable, and can be implemented within the required 24-month time limit set by statute. Figure 4-1 shows the conceptual layout of the major elements of the remedial measures plan. Prior to implementation of the proposed remediation, final design investigations and analyses will be performed, and construction drawings and technical specifications prepared. The specific layout, sizing, and construction materials will be determined during final design and may be different in some detail to the concepts presented below. However, changes will be made only if they provide results which are equal to or better than what is currently proposed.

4.2.1.1 Design Basis

The design bases for the various elements of remediation have been developed to meet the objectives discussed in Section 4.1 above, and the more specific purposes of the remediation techniques described below. The remediation techniques proposed and the bases for their conceptual design have been developed, in part, by appropriate application of selected Best Management Practices (BMP) developed by the Colorado Mined Land Reclamation Division (1988) for management of non-point sources, and in general accordance with the relevant reclamation practices of the Mineral Rules and Regulations of the Colorado Mined Land Reclamation Board (DMG, 1995). In addition, standard engineering practice is applied in all of the conceptual design. The following sections describe the various remedial measures proposed, their purpose(s), and key design standards.

4.2.1.2 Geohazards

No substantive engineering geologic or geotechnical issues have been identified with any of the remedial measures proposed for the site. There are no known significant geologic hazards with the potential to disrupt the remedial measures proposed.

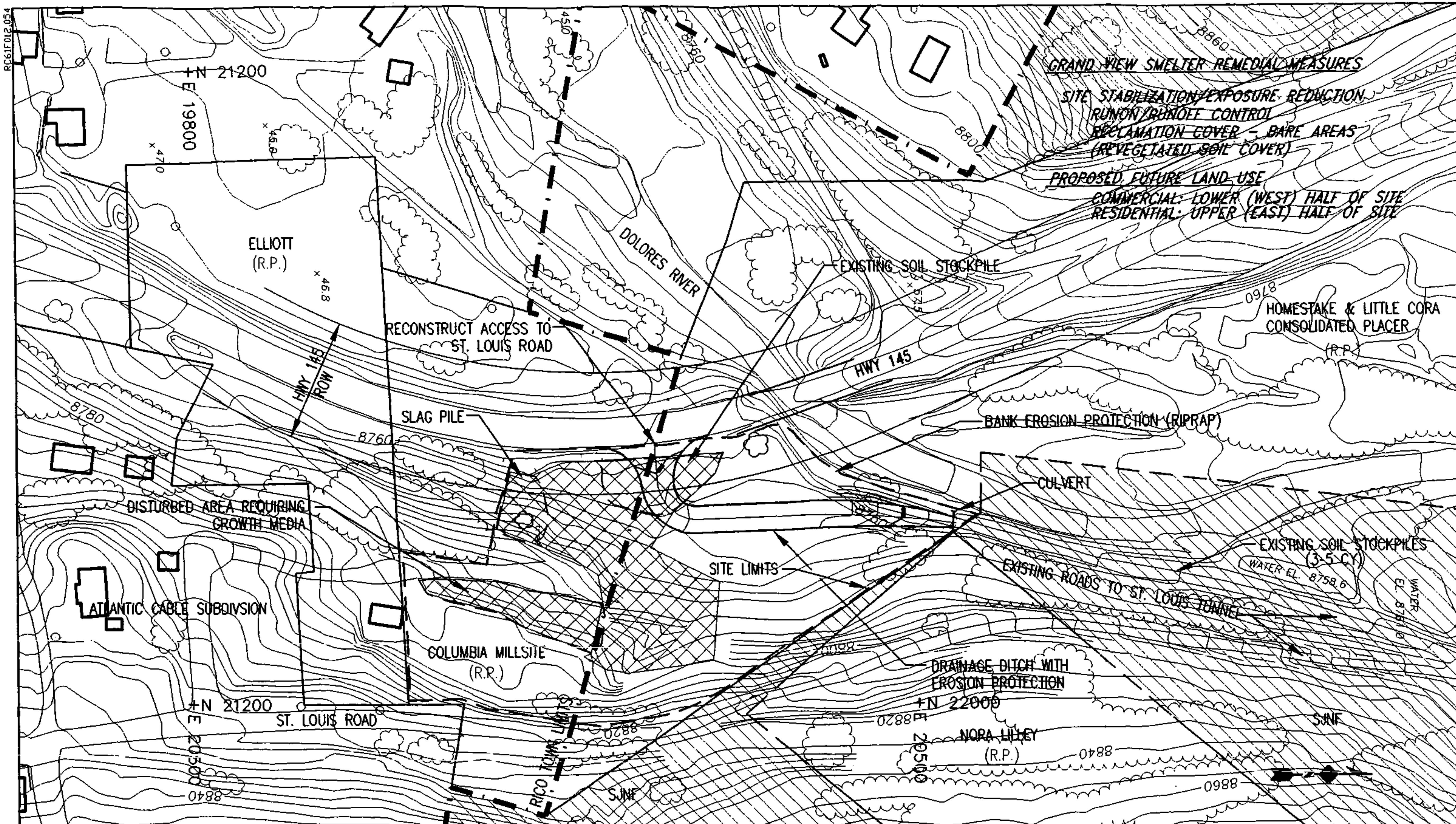
4.2.1.3 Site Access

Access to the Site is available on existing roads to and through the north end of Town. Access to the west side of the Site is from Highway 145 (new Site across road proposed). Access from the south is by existing dirt roads through the Atlantic Cable Subdivision and the Elliott claim (Figure 4-1).

4.2.1.4 Construction Site Controls

Construction controls will be implemented in accordance with the requirements of applicable federal, state or local permits, codes or regulations. In particular, construction drawings and specifications would identify and require implementation of appropriate Best Management Practices (BMPs) to protect contiguous land and the Dolores River from sedimentation during construction. These BMPs may include:

- Temporary grading, berms, straw bales, or other appropriate stormwater controls; and
- Detention of runoff from disturbed areas before allowing discharges into the Dolores River from the northwest corner of the Site upstream of the Highway 145 bridge.



LEGEND

BARE AREAS (±1.1 ACRES) TO BE RECLAIMED (REVEGETATED SOIL COVER); INCLUDES SOIL STOCKPILE AREA SOUTH OF RECONSTRUCTED ACCESS ROAD

SJNF SAN JUAN NATIONAL FOREST

R.P. RICO PROPERTIES, LLC

SCALE IN FEET

0 100 200

CONTOUR INTERVAL 2 FEET

REMEDIAL MEASURES

GRAND VIEW SMELTER SITE PLAN

FIGURE 4-1

4-12-96

RC61F775

RC61F012.054

BMPs would also be employed to control dust and spillage during borrow material earthmoving operations. These would include dust suppression at grading sites and on haul roads, and proper loading of haul trucks to prevent spillage.

All on-site construction and related activities will be conducted in strict conformance with a Site Specific Safety and Health Plan to be developed prior to mobilization. A Site Safety Officer will be designated to ensure that the requirements of the plan are met, and that safe work practices are implemented. Preliminary personal air monitoring and experience at other similar sites indicate that health risks will be minimal during earthmoving operations using appropriate BMPs.

4.2.2 Conceptual Design

4.2.2.1 Hydrologic Controls

Drainage Stabilization. Except for the northwest end, implementation of flood control measures are not applicable because the Site predominantly lies above the Dolores River valley corridor. The Dolores River flood hazard study by Dames & Moore (D&M, 1981) indicates that the toe of the northwest embankment would be inundated by flood events exceeding the 100-year event because the floodplain in this reach is controlled somewhat by the backwater effects of the highway bridge. The northwest embankment slope will be protected from flood flows and resultant erosion by the flood flows by the following remedial measure (Figure 4-1):

- *Riprap (or equivalent) slope and toe erosion protection for approximately 100 feet between the railroad bridge and the reconstructed access road.*

The purpose of the flood control measure is to prevent uncontrolled erosion and dispersal of historic smelter operation wastes to the Dolores River. The design standard to meet this objective is the 500-year frequency flood event with two feet of freeboard. Based on the Dames and Moore flood study, high velocity flows during the design event will be on the order of 11 fps and will require the use of large size riprap for erosion protection. Preliminary estimates of the design peak flood level indicate an inundation depth of about 7 feet above the bottom of the river channel immediately upstream of the highway bridge. At this level, the bottom 2 to 3 feet of the embankment slope would be inundated.

The design level (elevation) of erosion protection required to achieve 2 feet of freeboard along the embankment slope and sizing of the riprap will be determined during final design, using the Army Corps of Engineers methods for determining the design flood surface profile (HEC-2 method) and sizing of riprap (COE, 1991).

Runon Controls. The preferred alternative for runon controls involves the following remediation elements (Figure 4-1):

- *Stabilizing the Site to provide controlled conveyance of runon through the Site along with the runoff from the Site without causing erosion and dispersal of smelter wastes offsite; and*

- *Maintaining existing slopes across the Site, which are sufficient to promote controlled runoff and minimize infiltration.*

Runon will occur from precipitation and snowmelt from the disturbed partially forested watershed above the Site. The contributing drainage area for local runon from the uplands east of the Site is approximately 25 acres. Runon will be allowed to continue to flow through the Site and will be controlled through implementation of the runoff controls and reclamation cover described in the following sections.

Runon controls involving the use of water diversion structures to re-route upland surface water away from the Site are not proposed because the contributory drainage basin above the Site is relatively small (approximately 25 acres), no streams flow through the Site, and gully erosion is not a problem. In addition, two roads (i.e., the St. Louis Road and the Mill Road) cross the watershed above the Site (Figures 1-5 and 4-1). These roads are effective in interrupting the down slope flow path and thus reduce the velocity and peak flow of water flowing onto the Site. The roads also reduce the volume of runon reaching the Site somewhat because part of the flow from direct precipitation and runon is diverted away from the Site as flow down the surface of the roads and in roadside drainage ditches.

Runoff Control. Runoff controls, as shown schematically on Figure 4-1, involve the following remediation elements:

- *Maintaining existing slopes across the Site, which are sufficient to promote controlled runoff and minimize infiltration;*

- *Controlling runoff by concentrating sheet flow in drainage ditches; and*

- *Applying reclamation cover to disturbed slopes and smelter waste.*

Runoff from the Site occurs due to direct precipitation, snowmelt, and runon from upland hill slopes that drain to the east side of the Site. Runoff from the north half of the Site will be concentrated in a drainage ditch (rocky soil, stone or revegetated lining) along the new access road and directed offsite through a culvert to the Dolores River. The appropriate liner material for the ditch will be determined during final design based on a 100-year precipitation event of 2.6 inches (Miller, et al., 1973). Sheet flow from the south half of the Site will be allowed to continue to drain to the existing drainage ditch along the west side of the highway. As described below, the other fundamental runoff control and management practice used at the Site will be a reclamation cover for disturbed slopes and exposed smelter waste.

4.2.2.2 Reclamation Cover

The preferred alternative for reclamation cover to stabilize 1 acre of disturbed slopes and 0.1 acre of exposed smelter waste at the Site (Figure 4-1) includes the following elements:

- *Topsoiling, mulching, and revegetating exposed smelter waste and disturbed areas; and*
- *Revegetating Site areas where the results of previous reclamation efforts provide insufficient cover to minimize erosion.*

A comprehensive description of the agricultural characteristics of existing soil fill on the Site and revegetation plan for mining-related disturbances in the Rico district are presented in two reports prepared by Cedar Creek Associates (1995a and 1995b; provided with application under separate cover). Key elements of the revegetation plan applicable to the Grand View smelter site are summarized in the following paragraphs. Revegetation success criteria will be developed in accordance with the applicable Stormwater Permit. The Stormwater Management Plan will include provisions to maintain the cover until the vegetation has been established to the degree that standards (i.e., final stabilization criteria) are met under the appropriate permit.

The revegetation concept for the 0.35-acre area of combined smelter waste and disturbed ground that lacks adequate soil cover is to provide 12 inches of suitable growth media, mulch, and an appropriate seed mix. Approximately 600 cubic yards of growth media will be required for the Site. The source of the material will be the colluvial soil material stocked onsite near the highway and material hauled from a borrow source north of the St. Louis tunnel. The off-site borrow source is located about 0.75 mile north of the Site.

The general seed mix proposed for the Site, including the 0.75 acres of bare soil to be re-seeded, emphasizes native grass species, such as slender and streambank wheatgrass to adequately stabilize reclaimed surfaces. Other species are included based on their establishment potentials and to increase native species diversity (i.e., big bluegrass and mountain brome). In addition to the grasses, four forb species are proposed (Rocky Mountain penstemon, birdsfoot trefoil, cicer milkvetch and Lewis flax) based on their adaptive characteristics and positive aesthetic appeal. The mixture proposed for side slopes of roads and ditches where riprap or other high erosion resistance materials are not required, is simplified from the general mix. Species which do not add to the stabilization objective, and which might compete with more desirable species for available soil moisture and nutrients are excluded.

Samples of the prepared seedbed will be taken during reclamation to establish appropriate types and application rates of fertilizer. Fertilizer will be broadcast over the seedbed and incorporated by discing. The appropriate seed mix will then be broadcast and the surface slightly roughened to cover the seed. The seeded area will be mulched at a rate of 2 tons/acre following seeding with the mulch anchored by crimping.

4.3 Operations and Maintenance Plan

The VCUP should include: *"A remediation system operation and maintenance plan that describes, at a minimum, how the system will be operated to ensure that it functions as designed without interruptions and a sampling program that will be used to monitor its effectiveness in achieving the desired goal."*

The proposed VCUP for the site is intentionally comprised of remedial measures requiring the minimum practicable operations and maintenance and maximum practicable service life consistent with the applicable performance objectives, regulatory requirements, and anticipated future land uses. An overview of the anticipated O&M for the major elements of the proposed remedy is presented here. The specific requirements for operation and maintenance will be refined as part of final design.

No specific operations are required for the hydrologic control, slope stabilization or reclamation cover elements of the VCUP. The need for maintenance of these elements is also expected to be minimal, assuming that they are not subjected to loadings or disturbances for which they are not designed. An annual inspection by the property owner is recommended for the first five years after construction of the remedy to verify that the integrity of these measures has not been breached and/or to identify any conditions requiring maintenance (e.g., local disturbance of reclamation cover or channel erosion protection). In addition, an inspection should be made following severe precipitation events. The frequency and scope of inspections should be reevaluated after final stabilization criteria under the Stormwater Permit are met (and/or when future commercial/residential development occurs) and modified as appropriate based on the performance of the remedy and type of land development disturbance.

4.4 Management of Wastes Prior to Implementation of Remedial Action

"The plan should describe how the waste, or contaminated media will be managed prior to treatment, and/or disposal."

The remedial alternative does not include treatment or removal and disposal at an offsite location. There is no formal management of the Site. The Site lies on private property.

4.5 Hazardous Waste Generation

"The plan should discuss whether or not a hazardous waste will be generated by its implementation (e.g. through the excavation of contamination, which may have been discharged prior to 1980, but which would become a hazardous waste upon being dug up or managed), and the volume of this material. The plan should also describe how such hazardous waste will be managed in accordance with current state and federal hazardous waste regulations."

No hazardous waste will be generated by implementation of the VCUP.

4.6 Verification Sampling Program

"If applicable, the plan should describe the sampling program that will be used to verify that treatment of the contaminated media has resulted in a non-hazardous waste."

The proposed remedial alternatives for the Site does not include the treatment of historic smelter operations waste material. Therefore, a verification sampling program is not applicable.

4.7 Remediation Risk Analysis

No significant short- or long-term risks have been identified for the remediation proposed in this VCUP. Short-term (implementation/construction period) risks will be typical of those for any earthmoving project, and are readily manageable so as to effectively avoid any significant environmental or health and safety consequences. As discussed in Section 4.2.1.4, construction controls will be fully implemented to protect the Dolores River, and undisturbed lands adjacent to the work areas and/or offsite from uncontrolled releases of sediment or mine waste. The technologies to be employed for the proposed remediation, and the construction control BMPs are simple, have been used successfully for decades, and are readily controlled and verified by on-site inspection and supervision of the work.

All on-site construction and related activities will be conducted in strict conformance with a Site Specific Safety and Health Plan to be developed prior to mobilization. A Site Safety Officer will be designated to ensure that the requirements of the plan are met, and that safe work practices are implemented. Preliminary personal air monitoring and experience at other similar sites suggests that health risks will be minimal during earthmoving operations using appropriate BMPs.

Potential long-term risks to the integrity of the proposed remediation at the Site include natural processes or hazards such as erosion and floods (Dolores River embankment), and man-induced disturbances such as inappropriate land use. The design of the various elements of the remediation according to BMP's and standard engineering practices will effectively mitigate the potential for significant damage and/or release of sediments or waste from historic smelter operations under the design events adopted (e.g., 100-year precipitation event/500-year flood). Design, construction and maintenance of the remediation measures under these types of standards have demonstrated constructability and effectiveness on innumerable projects of similar scope and conditions. The potential for man-induced disturbances is effectively addressed by land use and related institutional controls as described in Section 4.8.

The technical and economic feasibility of the proposed remediation at the Site derives from the nature, scope and relative simplicity of the design and implementation of the plan as described above.

4.8 Land Use/Institutional Controls

The proposed land use will be as a continued historic smelter waste site with future controlled commercial and/or residential development (residences previous existed on the east side of the property). Maintenance for the uses will largely be self-implementing. ARCO and the current landowner Applicant will work to ensure continued coordination and site maintenance. Some of the mechanisms currently being evaluated for the private parcel within the town limits include application of Rico planning and development regulations, zoning, use easements, restrictive covenants, and conservation easements. Dolores County planning and development codes and regulations apply to the parcel outside of the town limits.

4.9 Permit Requirements

"The plan should identify all permits (Federal, state and/or local including, if necessary, EPA Form 8700-12-Notification of Hazardous Waste Activity, required on the generation of hazardous waste) that will be needed before the plan can be implemented."

Two general areas involving permitting or application of government approval issues have been identified:

1. NPDES/Dredge and Fill Permits. All work performed within the existing drainage will comport with appropriate U.S. Army Corps of Engineers ("Corps"), EPA, and State standards under these programs, and the Applicants will continue to work closely with regulatory agencies on these matters. Although formal government approval under the NPDES program does not appear necessary based on current reclamation-based measures, appropriate stormwater notices will be provided. Approval from the Corps will likely come through existing Section 404 nationwide and/or regional permits. In any case, best management practices associated with construction activities along the Dolores River, including stormwater controls will be employed.

2. Reclamation Standards. While no reclamation permit will be required from the Colorado Mine Land Reclamation Division ("MLRD") or other agencies, the applicants will consider and apply appropriate MLRD standards to those aspects of the project involving traditional reclamation activities.

4.10 Schedule of Implementation

"The plan should include a schedule of implementation."

Implementation of remediation for the Site will begin immediately upon approval of the VCUP. The major required activities in their general order of implementation are:

- Final design engineering and preparation of construction documents
- Permitting
- Project procurement (bidding, negotiation, award)
- Construction

As appropriate, certain of these activities and/or specific sub-activities would be performed with overlap or concurrently. It is anticipated that engineering through review is achievable within one month of the start date. Project procurement can be completed in two months. These activities generally are not seasonally (weather) dependent, with the exception of final design field investigations, as needed, and site surveying. Construction, on the other hand, is highly dependent on weather.

The construction season at the Site is from May 1 to October 15. The duration of construction activities is estimated at 3 weeks. The construction would not be split between two seasons due to potential damage to uncompleted parts of the work, greater risk of offsite sediment releases, and higher costs associated with winterization, remobilization and repair of any damaged work.

Given the factors and conditions discussed above, the required 24 month time limit for implementation of the remedial measures can be met under the following conditions:

- Any necessary permits are attained in a reasonably timely manner;

- The construction season is not significantly impacted by extremely severe weather;

- Any necessary reviews of construction drawings and technical specifications are performed in a timely manner; and

- Seasonally dependent activities (i.e., seeding) are not delayed into the following year.

4.11 References

Cedar Creek. 1995a. Characterization of soil/solid waste for proposed voluntary remediation of mining-related disturbances in Rico, Colorado. Report prepared for Atlantic Richfield Company, Denver, Colorado and ESA Consultants Inc., Fort Collins, Colorado. Cedar Creek Associates, Inc., Fort Collins, Colorado. September.

Cedar Creek. 1995b. Revegetation plan for proposed voluntary remediation of mining-related disturbances in Rico, Colorado. Prepared for Atlantic Richfield Company, Denver, Colorado and ESA Consultants, Inc., Fort Collins, Colorado. Cedar Creek Associates, Inc., Fort Collins, Colorado. September.

COE. 1991. Hydraulic design of flood control channels. Engineer Manual EM 110-2-1601. U.S. Army Corps of Engineers, Washington, D.C.

Colorado Mined Land Reclamation Division. 1988. Appendix C, Recommended Best Management Practices for Abandoned and Inactive Mining; in Water Quality Management Practices for Non-Point Source Pollution Related to Mine Waste and Mine Drainage; November.

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DMG. 1995. Mineral Rules and Regulations of the Colorado Mined Land Reclamation Board. Effective May 1977. Amended January 1995. State of Colorado, Division of Minerals and Geology.

Miller, J.F., et al. 1973. Precipitation-Frequency Atlas of the Western United States. NOAA Atlas 2, Volume III-Colorado, Department of Commerce, U.S. National Oceanic and Atmospheric Administration.

APPENDIX A

QUALIFICATIONS OF ENVIRONMENTAL PROFESSIONALS

- **Applied Geology**
- **Cedar Creek Associates, Inc.**
- **ESA Consultants Inc.**
- **Titan Environmental**

APPLIED GEOLOGY

TRAVIS L. HUDSON, Ph.D.
Geologist
APPLIED GEOLOGY

EDUCATION:

Ph.D., Geology, Stanford University, 1976
M.S., Geology, Stanford University, 1973
B.S., Geology, San Jose State University, 1968

EXPERTISE:

- Over 25 years experience in the application of geosciences to solving basic research, natural hazards, mineral resource assessment, mineral exploration, hydrocarbon exploration, and environmental problems.

- Description, mapping, and analysis of surficial geology in support of natural hazard evaluation and environmental characterization.

- Geochemical characterization and analysis with an emphasis on understanding natural controls on element distributions.

- Synthesis and integration of geoscience data necessary to understanding natural processes.

- Multidisciplinary technical project development and management in support of practical geoscience applications.

- Remediation technology development for mining-related sites.

REPRESENTATIVE PROJECT EXPERIENCE:

Surficial Geology; Earthquake-Generating Faults, Alaska. Detailed description, mapping and dating of surficial geology (soils, colluvium, alluvium, glaciofluvial deposits, loess, etc.) and geomorphic features (scarps, drainage offsets, fault traces, sag ponds, etc.) of the Fairweather, Castle Mountain, Denali, and many other smaller faults.

Surficial Geology; Lituya Bay Marine Terraces, Alaska. Description, mapping, and dating of surficial geology (soils, beach deposits, glaciofluvial deposits, moraines, etc.) and geomorphic features (beach ridges, sea stacks, shoreline angles, sea cliffs, peat bogs, and spruce forests of different ages) on a sequence of four marine terraces extending for 60 miles along the east coast of the Gulf of Alaska.

Igneous Rock Geochemistry, Alaska. Mapping, representative sampling, and data analysis to determine the major and minor element character of unaltered and altered igneous rocks associated with tin deposits, molybdenum deposits, magmatic arcs, and crustal melting.

Characterization of Mineral Deposits, Alaska. Description, mapping, compilation, and synthesis of information on tin deposits, molybdenum deposits, and gold deposits.

Soil and Sediment Geochemistry, Alaska. Sampling and data analysis to determine the distribution of minor elements in rocks, soils, and stream sediments for regional mineral resource assessment and base metal, precious metal, and tin exploration. Projects have included the collection of thousands of samples, statistical analyses to clarify sample results, and extensive evaluations of background and natural metal distributions in order to correctly define anomalies.

Technical Evaluation of Site Characterization Data, Bingham Creek, Utah. Technical review of analytical data for stream sediments, tailings, agricultural surface materials, and ground water to define sources and origins of contaminants.

Technical Evaluation of Remedial Alternatives, Montana. Technically reviewed remedial designs in RODS and developed conceptual alternatives to be evaluated for Streamside Tailings, Lower Area One, and Berkeley Pit operable units.

Remediation Technology Development. Developed, managed, and technically contributed to ARCO's remediation technology development for mining sites project. This project identified 55 alternative technologies and approaches for remediating and/or redeveloping mining-related sites.

PROFESSIONAL AFFILIATIONS:

Geological Society of America, Fellow
Society of Economic Geologists
American Association of Petroleum Geologists
Geological Association of Canada

PUBLICATIONS:

Over 100 reports documenting work results including articles in several referred earth science journals. Numerous presentations to management, professional societies, regulatory agencies, and the public.

CEDAR CREEK ASSOCIATES, INC.

CEDAR CREEK ASSOCIATES, INC.

STEPHEN G. LONG

EXPERIENCE ABSTRACT

Employed for 17 years in the environmental field, 15 as a consultant with multi-disciplinary responsibilities including service as corporate officer, project manager/strategist, revegetation specialist, soil scientist, revegetation field supervisor/coordinator, wetlands specialist and vegetation/wildlife field technician. Project management responsibilities have included client/agency liaison, project risk analysis, technical editing, personnel management, cost control, and quality assurance evaluation. Experience also includes mine inspection and personnel management.

Career accomplishments include authorship of, or technical contribution to:

65 Revegetation Plans • 27 EIS/EA documents • 23 Bond/Construction Cost Estimates • 5 Revegetation Test Plot Programs • 12 Mine Permit Reviews/Revisions • 44 Wetland Projects • 21 Vegetation Surveys • 13 Soil Surveys • 12 Wildlife Surveys • 19 Property Transfer Evaluations • Permit Strategy Development for Numerous Projects • 2 Revegetation Manuals and 8 Technical Papers • Expert Witness Testimony and Lectures

Types of projects have included:

Hard Rock Mines • Wetland Disturbances • Municipal Developments • Pipelines • Water Projects • Coal Mines • Corridor Analyses • Gas and Synfuels Developments • Abandoned Mines • Power Plants • Gravel and Borrow Pit Permits • Real Estate Projects and Other Private Land Holdings • Golf Courses

Involved in over 135 projects including work in:

Northern Great Plains • Rocky Mountains • Desert Southwest • Pacific Northwest • Intermountain Region • Appalachia • California • Alaska

EDUCATION AND CERTIFICATIONS

B. S., Wildlife Biology, Colorado State University - 1972
M. S., Regional Resource Planning/Soil Science-Reclamation, Colorado State University - 1977
Associate Wildlife Biologist - The Wildlife Society
Certified Soil Erosion and Sediment Control Specialist - ARCPACS
40-Hr. OSHA Certification (OSHA Reg 29 CFR 1910.120)
Desert Tortoise Survey and Examination Techniques
Black-footed Ferret Survey Techniques- U. S. Fish and Wildlife Service

EMPLOYMENT HISTORY

Cedar Creek Associates, Inc. - 1982 to Present
Environmental Research & Technology, Inc. - 1977 to 1982 (Presently ENSR)
Ohio Department of Natural Resources, Division of Reclamation - 1972 to 1974

REPRESENTATIVE CLIENTS

Anaconda Copper Co. (NV) • Atlantic Richfield Co. (CO) • AT&T (NV) •Chevron Shale Oil Co. (CO) • City of Bellevue (OH) • City of Boulder (CO) • City of Fort Collins (CO) • Coaleum Corp. (W.V) • Consolidation Coal Co. (ND) • Coteau Properties Co. (ND) • Diamond Shamrock Corp. (AK) • Eureka Energy Co. (UT) • Exxon Minerals Co. (NM) • Falkirk Mining Co. (ND) • Freeport Gold Co. (NV) • Getty Mining Co. (CO) • Goldenbell Mining Corp. (CA) • Gulf States Energy Corp. (KY) • Hewlett-Packard Co.(CO)• Houston International Minerals Corp. (NV) • J & P Corp. (WY) • Montco (MT) • Northwest Pipeline Corp. (CO) • Northern Tier Pipeline Co. (MN, MT, ND, WA) • Peabody Coal Co. (MT) • Platte River Power Authority (CO) • Retech (CO) • Rocky Mountain Energy Co. (WY) • Simons, Li & Associates, Inc. (CO, UT, WA, Africa) • Sunedco (UT) • Texas Energy Services, Inc. (WY) • Town of Breckenridge (CO) • U. S. M. X. (NV) • U. S. Congress (Western U. S.) • U. S. Fish and Wildlife Service (Western U. S.) • U. S. Forest Service (ID, MT, NV) • Utah Division of Oil, Gas and Mining (UT)

EXPERIENCE SPECIFICS

Mr. Long's education and years of environmental and regulatory compliance experience have facilitated the development of specialized multi-disciplinary skills for use on mining, wetland disturbance, urban and water development, power plant construction, and corridor assessment/restoration projects. His areas of expertise include permitting and project management, revegetation planning, wetland delineation and mitigation, soil science, and wildlife habitat restoration, among others.

PERMITTING AND PROJECT MANAGEMENT. Mr. Long has successfully managed, coordinated, and overseen development of technical documents for projects varying widely in size, scope, and objectives. Responsibilities have included project/permit strategy development, technical editing, cost analysis, personnel scheduling, and quality control. He frequently serves in a liaison capacity between clients and regulatory agencies. In addition, Mr. Long has successfully reviewed, edited, and revised sections of existing deficient permit applications and achieved subsequent regulatory approval. In a related capacity, Mr. Long completed 19 on-site property and permit evaluations for private companies seeking to expand their holdings. He also has contributed to 27 NEPA documents for various permit documents. Examples of permitting projects in which he has participated or managed, include various state and federal coal mine and hard rock permit applications, CMLRD gravel mine applications, and Corps of Engineers Nationwide 26, PDN-26, and "Individual" permit applications.

REVEGETATION. Mr. Long has completed revegetation and restoration plans for 65 disturbances including those associated with surface and underground coal mines, hard rock mines, wetlands, municipalities, water developments, abandoned mines, pipeline and power plant construction sites, and synfuels exploration disturbances. These plans addressed a wide range of general objectives including site stabilization, erosion control, reestablishment of livestock grazing capacity, critical big game winter range, and aesthetics as well as specific objectives such as wetland and riparian system restoration, woody draw reconstruction, and moose and pronghorn antelope habitat enhancement. Typical plans include a soil handling program with soil mass balancing, site preparation details, fertilizer application recommendations, planting procedures, site-specific planting mixtures, soil stabilization specifications, and maintenance recommendations as well as bond/construction cost estimates. In addition, Mr. Long has been involved in the design and implementation of five revegetation test plot projects completed to determine the effects of slope, aspect, seeding and planting methods, species selection, seedbed material type, and time of seeding on revegetation success potential. He has coordinated and personally implemented revegetation and erosion control programs in the field and served as a revegetation inspector in Ohio with responsibility over 61 active mine operations. Mr. Long has served as an expert witness on the subject of revegetation for two hearings. He has authored two revegetation manuals, Characteristics of Plants Used in Western Reclamation and Handbook of Revegetation Techniques, which have received wide academic, regulatory, and industry distribution throughout North America.

SOIL SCIENCE. Mr. Long has participated on 13 Order 2 and Order 3 soil survey projects designed to characterize soil properties and develop soil handling plans. He has completed numerous field sampling projects designed to assess seedbed material growth potential capabilities, soil microbial populations, soil fertility conditions, and toxic constituent levels. In addition, Mr. Long has evaluated a wide range of soil mapping and laboratory data culminating in his authorship of several soil technical reports for EIS, EA, pipeline corridor, and mine permit documents.

WETLAND BIOLOGY, RANGE SCIENCE, and WILDLIFE. Mr. Long has completed 44 wetland mapping, permitting, and/or restoration projects in the west, responsive to COE, state and local regulations. He has been involved in 21 vegetation surveys responsive to various permitting requirements. Vegetation experience includes measurement of plant density, canopy cover, diversity, and current annual production as well as specific surveys for T&E species. Wildlife experience includes participation in aerial or terrestrial surveys for mule deer, antelope, mountain goats, black-footed ferrets, goshawks, determination of big game distributions, and preparation of wildlife report sections. He also has experience in desert tortoise monitoring (450 field hours) for construction projects.

PUBLICATIONS

Fullerton, W.T. and S.G. Long. 1989. Wetland creation in a river valley disturbed by dredge boat mining. pp. 297-306. In: Fisk, D.W. (Ed.). Wetlands: Concerns and Successes (Symposium Proceedings). Tampa, Florida. American Water Resources Association. Bethesda, Maryland.

Long, S. G. 1978 (first edition). 1980 (second edition). Characteristics of plants used in western reclamation. Environmental Research & Technology, Inc., Fort Collins, Colorado. 138 pp.

Long, S. G. 1982. Analysis of geotextiles and their potential use in cut-and-fill revegetation. U. S. Forest Service, Missoula, Montana.

Long, S. G. 1985. A seeding technique to enhance species diversity. pp. 279-282. In: Williams, D. and S. E. Fisher, Jr. (Co-chairmen). Second Annual Meeting: American Society for Surface Mining and Reclamation. Denver, Colorado.

Long, S. G. and S. L. Ellis. 1984. Revegetation guideline development for pipeline rights-of-way. pp. 233-244. In: Crabtree, A. F. (Ed.). Proceedings of the Third International Symposium on Environmental Concerns in Rights-of-Way Management, San Diego, California. Mississippi State University, Mississippi.

Long, S. G. and S. L. Ellis. 1987. Results of woody species test plots established on a mine exploration site in Alaska. pp. 245-258. In: Schuster, M. A. and R. A. Zuck (Eds.). Proceedings: High Altitude Revegetation Workshop No. 7. Colorado State University, Fort Collins, Colorado.

Long, S. G., J. K. Burrell, N. Laurenson, and J. H. Nyenhuis. 1984. Handbook of revegetation techniques (cut-and-fill slopes, mined lands, watershed projects, range improvements). U. S. Forest Service. Missoula, Montana. 145 pp.

Lynch, D. L. and S. G. Long. 1977. A management plan for the McGregor Ranch (Estes Park, Colorado). Colorado State University, Fort Collins, Colorado. 46 pp.

Phelan, T. M., S. R. Viert, and S. G. Long. 1986. Wildlife technologies for western surface coal mining. pp. Office of Technology Assessment, U. S. Congress, Washington, D. C. 183 pp.+ appendices.

Contributing Author to:

Moore, R., and T. Mills. 1977. An environmental guide to western surface mining, part two: impacts, mitigation, and monitoring. Western Energy and Land Use Team, U. S. Fish and Wildlife Service Publication FWS/OBS - 78/04. Misc. pagings.

Numerous technical discipline reports concerning revegetation, wetlands, soil science, vegetation, and other environmental topics

STEVEN R. VIERT

EXPERIENCE ABSTRACT

Employed as an environmental consultant since 1977. Responsibilities include service as corporate officer, project manager, permitting specialist, range ecologist, and wildlife biologist. Project management activities include interdisciplinary coordination, subcontractor supervision, client/agency liaison, cost control, critical path scheduling, overall planning, and quality assurance.

Career accomplishments include authorship of, or technical contribution to:

43 NEPA Documents • 21 Permit Evaluation/Audits/Revisions • Strategy Development, Agency Liaison, Permit Preparation for Numerous Projects • 71 Vegetation Baseline/Community Mapping Studies • 66 Vegetation Impact Assessments • 37 Wetland Evaluations • 32 Revegetation Success/Bond Release Determinations • 51 Wildlife Baseline/Habitat Studies • 46 Wildlife Impact Assessments/Mitigation Plans • Threatened and Endangered Species Evaluations (37 flora, 35 fauna) • 15 Land Use Evaluations/Reviews • 4 Alluvial Valley Floor Assessments • State-of-the-Art Riparian Investigations & Expert Witness Testimony • Management of 2 Complete Coal Mine Permit Applications

Types of projects have included:

Hard Rock Mines • Coal Mines • Litigation Support • Wetland Evaluations/Enhancement • Riparian Assessments • Corridor Analyses • Water Developments • Synfuels Projects • Abandoned Mines • Power and Other Industrial Plants • Superfund Remedial Investigations

Involved with 170 projects including work in:

Desert Southwest • Northern and Central Great Plains • Rocky Mountains • Pacific Northwest • Intermountain Region • West Coast • Midwest • Alaska

EDUCATION AND CERTIFICATIONS

B. S., Wildlife Management, University of Michigan, 1974
M. S., Range Ecology, Colorado State University, 1975
M. B. A., Finance/Land Use Management, Colorado State University, 1982
Certified Wildlife Biologist - The Wildlife Society
Certified in Habitat Evaluation Procedures (HEP) - U. S. Fish and Wildlife Service
Black-footed Ferret Survey Techniques - U. S. Fish and Wildlife Service
Desert Tortoise Survey and Examination Techniques

EMPLOYMENT HISTORY

Cedar Creek Associates, Inc. - 1982 to Present
Environmental Research & Technology, Inc. - 1977 to 1982 (presently ENSR Corporation)
Colorado Division of Wildlife - 1974 to 1975

REPRESENTATIVE CLIENTS

AT&T (CA,.NV) • BHP-Utah International Inc. (UT) • Chevron Shale Oil Co. (CO) • Cities of Boulder, Breckenridge, Fort Collins, Loveland, and Pueblo (CO) • Colorado Attorney General • Diamond Shamrock Corp. (AK) • El Paso Natural Gas Co. (NM) • Energy Fuels Co. (CO) • Exxon Minerals Co. (NM) • Falkirk Mining Co. (ND) • FMC Gold Corp. (ID, MT, NV, WY) • Freeport Gold Co. (NV) • Getty Mining Co. (CO) • Homestake Mining Co. (NV) • Inspiration Mining Co. (NV) • Kern River Gas Trans. Co (WY) • Meridian Land & Minerals Co. (MT, CO, NV, SD) • North American Coal Co. (ND) • Office of Technology Assessment, U.S. Congress (Western U.S.) • Pacific Gas and Electric Co. (UT) • Peabody Coal Co. (AZ, CO, WY) • Platte River Power Authority (CO) • Rocky Mountain Energy Co. (WY) • Simons, Li & Associates, Inc. (CO, UT, WA, Africa) • Sunedco Coal Co. (UT) • BLM (AZ, UT, NV) • USFS (ID, MT, NV) • U.S. Sprint (CA,ND) • Utah DOGM (UT) • Western Energy Co. (MT) • W.R. Grace Co. (UT) • WIDCO (WA)

EXPERIENCE SPECIFICS

Mr. Viert's education and several years of environmental and regulatory compliance experience have facilitated development of specialized multi-disciplinary skills for projects in mining, industrial and urban land development or rehabilitation, corridor assessment, wetland evaluation/restoration, and water development. Areas of expertise include permitting and project management, vegetation and range ecology, wildlife / habitat ecology, bond release evaluations, and land use classification/evaluation.

PERMITTING AND PROJECT MANAGEMENT. Mr. Viert has been actively involved in all phases of permit application development from feasibility analyses to the assessment of reclamation success for the release of bonds. Permitting and management responsibilities have included overall permit preparation, strategy formulation, client/agency liaison, regulatory compliance evaluation, subcontractor supervision, critical path scheduling, cost control, quality assurance, and technical document editing for a variety of projects. Permitting projects have ranged from small 404 applications to large NEPA compliance efforts. Of particular note are two large management efforts leading to the successful acquisition of SMCRA permits for a 12.5 million TPY coal mine in the Powder River Basin of Wyoming and a 5 million TPY underground coal mine in the Book Cliffs of Utah. Mr. Viert's permitting experience and related interactions with regulatory agencies for development projects and associated permit application submittals have provided him with a working knowledge of the policies and regulations of several state and federal agencies such as OSMRE, COE, NRC, FERC, BLM, USFS, USFWS, CMLRD, WDEQ, UDOGM, NDPSC, NM-MMD, NDEP., among others. Mr. Viert's project management experience has been gained on projects ranging from single discipline evaluations (e.g., wetlands) to large multi-disciplinary efforts (including engineering, legal, environmental, and reclamation) for mining and other development projects.

VEGETATION/RANGE ECOLOGY. Mr. Viert has completed over 90 vegetation studies and assessments for a wide range of projects including litigation (riparian issues between the state of Colorado and the USFS), surface and underground coal mines, hard rock mines, synfuel developments, corridor assessments for power and communication lines, pipelines and transportation arterials, water developments, abandoned mines, and municipal developments. Study components of these projects have included: floral measurements (cover, density, production, etc.), statistical design and analyses, community mapping, impact assessment and mitigation planning, determination of general range condition and community dynamics, evaluation of livestock carrying capacity and management, forest measurement, and development of revegetation success standards and bond release criteria. In addition, he has evaluated sensitive issues such as wetlands and threatened and endangered species. He also has assisted in the development of several revegetation planning efforts and, as discussed below, designed and implemented a ~~number~~ studies for post-revegetation monitoring to determine revegetation success for bond release. In 1977, Mr. Viert pioneered the development and use of the Optical Point Bar, a new instrument for economically and precisely measuring ground cover which is used in most analyses of vegetation.

RECLAMATION SUCCESS AND BOND RELEASE DETERMINATIONS. In this specialized field, Mr. Viert has been very actively involved in state-of-the-art design and implementation of site-specific technical studies for a large number of mining companies, especially coal. These studies are designed to be the most potentially successful, defensible, practical, and economical methods of analyses to facilitate the release of bond monies. Mr. Viert has successfully negotiated with State and Federal Agencies for both the implementation of such designs as well as aided negotiations for the eventual release of bonds.

WILDLIFE BIOLOGY. In this field, Mr. Viert has been actively involved in over 60 wildlife studies and impact assessments for various mines and land developments. Technical capabilities in this field include habitat evaluation and mapping, large mammal population studies, upland game animal surveys, general baseline measurement, sensitive and threatened or endangered species evaluations [especially for black-footed ferret and desert tortoise (over 1600 hours of survey/monitoring)], impact assessment, state-of-the-art mitigation planning, and aquatic sampling.

OTHER technical capabilities include land use assessment and classification, alluvial valley floor evaluation, and farm/ranch economic assessment.

PUBLICATIONS

Viert, S. R. 1989. Design of restoration methods to encourage fauna. In: J. D. Majer, PhD (Ed.). Animals in primary succession - the role of fauna in reclaimed land. Cambridge University Press, London, England.

Viert, S. R. 1985. A new instrument for measuring ground cover based on the point-hit technique - the optical point bar. Proceedings of the 1985 Annual Meeting of the American Society for Surface Mining and Reclamation, Denver, Colorado, October 8-10. 4 pp.

Phelan, T. M. and S. R. Viert. 1986. Prairie dog and black-footed ferret surveys in northeast and east-central Utah. Cedar Creek Associates, Inc. 31 pp. + appendices.

Phelan, T. M. , S. R. Viert, and S. G. Long. 1986. Wildlife technologies for western surface coal mining. Office of Technology Assessment, U. S. Congress, Washington, D. C. 183 pp. + appendices.

Numerous technical discipline reports concerning vegetation, range ecology, wetlands, wildlife, and other environmental topics

1/95

ESA CONSULTANTS INC.

EDMUND J. SCHNEIDER, P.G.
Associate Hydrologist/Engineering Geologist

Academic Credentials
M.S., Geology, Colorado State University, 1975
B.S., Wildlife Biology, Colorado State University, 1968

Professional Licenses
Professional Geologist, Wyoming
OSHA Health/Safety Training for Hazardous Waste Operations
40-hr and 8-hr Supervisory Certification

Key Qualifications

Mr. Schneider is a registered professional geologist with over 20 years of varied experience in hydrogeology, engineering geology and environmental geology. His responsibilities have included project management and technical investigations in soil, geologic and environmental hazard assessments, ground-water quality assessment, data management/data validation, remedial investigations and design, and remedial action construction oversight. Mr. Schneider's hydrogeology and ground water experience ranges from non-intrusive investigations of regional and site-specific hydrogeology and ground-water flow conditions to intrusive field studies for characterization of hydrostratigraphy, ground-water flow paths and aquifer hydraulic properties for a variety of water supply, construction dewatering, environmental impact and hazardous waste site assessments, and remediation projects. His environmental geology project experience includes document reviews, aerial photograph interpretation, site reconnaissance, field mapping, intrusive soil and ground-water investigations, data management/data validation, and geologic hazards assessment. His recent relevant Superfund experience includes engineering evaluation/cost analysis, feasibility studies (alternatives analysis), remedial design and construction oversight/quality control. Mr. Schneider is also experienced in preparation of permit applications, expert testimony at permit hearings, negotiation with regulatory agencies on a variety of environmental investigation/remediation projects, and preparation and implementation of site-specific health and safety plans in accordance with OSHA 29 CFR 1910.120.

Relevant Related Experience

- *Warm Springs Ponds Inactive Area Operable Unit Remedial Action Construction, Montana.* In addition to his technical responsibilities at this site, Mr. Schneider served as Project Manager for construction oversight services for all phases of construction activities, including technical support, field inspections, materials testing and construction quality control. Assistance was also provided for monthly progress reports, agency site inspections, surveying subcontract services, field design modifications, and post-construction activities, including environmental monitoring and operations/ maintenance plans, construction completion report/as-built drawings, and pre-final and final construction inspections. Mr. Schneider directed a field staff of 2 to 4 inspectors, an office staff of 4 engineers, and several subcontractors to accomplish the various oversight tasks.

- *Warm Springs Ponds Operable Unit Soil and Ground Water Remediation, Butte/Silver Bow Creek NPL Site, Montana.* Served as environmental soils investigation leader and hydrogeologist for this operable unit. Mr. Schneider was responsible for development of an ore tailings and associated soils removal protocol on behalf of the client, in lieu of definitive EPA or State of Montana action level criteria for soil remediation. Development of the removal protocol involved extensive field exploration, soil analysis for heavy metals of concern, and statistical quantification of analytical data by material type and by depth within the affected soil profile. The protocol was approved by the EPA and applied effectively during the removal of approximately 430,000 cubic yards of tailings and associated soil materials from a three-mile reach of stream channel to protect the fishery in the Clark Fork River downstream of the site. In addition, Mr. Schneider was responsible for the assessment of ground-water quality and aquifer hydraulic properties required for the analysis and design of ground-water control systems, including ground-water interception and treatment for heavy metals.

- *Rico Site Environmental Assessment Support-Document Review.* Mr. Schneider served as Project Manager in the review of ARCO Rico Site archived files/documents and various other related sources of information. Discharge data and historic water quality data was compiled as a summary of the site background and an annotated bibliography of over 200 database records was created to assist ARCO in the Rico Site Environmental Assessment.

- *Great Falls Refinery Site Assessment, Montana.* Mr. Schneider supported operations in the development/implementation of a successful surface and ground water drainage control program and site reclamation for decommissioned metals refinery facility to alleviate potential off-site releases of heavy metals to the Missouri River. Conducted scoping study to identify extent of impacts to site soils and surface water quality associated with prior metals refining operations and solid waste management. He was responsible for development/management of the soil and surface/water quality studies, data reduction and analysis, and report preparation. Follow-up work included site inspection and recommendations for construction of stable reclaimed fill slopes and lined drainage ditches.

- *Summitville Superfund Site Assessment, Colorado.* Reviewed technical documents from extensive administrative record and conducted site reconnaissance at NPL site subject to severe acid mine drainage conditions for confidential client. The study focused on a qualitative assessment to compare/contrast historic mining/milling operations with recent open pit gold mine/cyanide heap leach operations as major sources of hazardous substances and acid mine drainage in anticipation of potential litigation.

- *Diesel Fuel Spill, Nevada Moly Mine Site, Nevada.* Conducted site investigations to determine extent of infiltration of a diesel fuel spill from storage tank. Investigation included review of operational circumstances associated with the spill, quantity spilled and field excavations to examine depth of infiltration into the ground. A quantitative analysis, based on API guidelines, was performed to confirm that residual fuel in the ground did not pose a potential threat to ground-water quality.

- *Other Site Assessment Experience.* In addition to the previous described experience, Mr. Schneider has participated other assessment projects as follows: Project Manager/Hydrogeologist, historical mining-related sources heavy metals in the ground and shallow ground water, Butte, Montana; Technical Specialist, Twin Buttes Mine/Mill ground-water quality assessment, Arizona; Project Manager/Hydrogeologist, Butte West Camp underground mine flooding assessment and control alternatives analysis, Montana; Solid Waste Specialist, PCB transformer assessment for potential historic mine/mill site acquisitions, Colorado; assessed potential impacts to ground water and provided expert testimony for approved Underground Injection Control permit application for of sewage treatment plant effluent as an acceptable alternative to a point discharge to the prestine Snake River, Wyoming.

Publications

Nuckolls, H.M., Yadon, D.M., and Schneider, E.J., 1991, Remediation of Mining Wastes, Silver Bow Creek/Butte Area Superfund Site, Montana: presentation to the Irish Association for Economic Geology Course on Environmental Aspects of Exploration and Extraction.

GARY R. WINDOLPH, P.E.

Vice President
Principal Civil Engineer

Academic Credentials

B.S., Civil Engineering, University of Nebraska, 1964
Graduate Studies, Environmental Engineering and Business Administration, University of Nebraska, 1964-66

Professional Licenses

Professional Civil Engineer: CO, WY, NE, UT, TX, PA
OSHA Health and Safety Training 24 hr Certification for Hazardous Waste Site Operations

Key Qualifications

Mr. Windolph is Division Manager for ESA's Fort Collins office and serves as a principal civil engineer directing feasibility level through final design activities for civil and CERCLA projects. He provides consultation, management and QA/QC for major projects. From 1991-1994, Mr. Windolph held a United Nations appointment as an advisor to the Government of Sri Lanka, providing advice and assistance in the areas of environmental policy development and management.

From 1978 to 1990 Mr. Windolph was President/CEO/Director and Principal Engineer of ARIX Corporation, a consulting engineering company having offices in four states and employing over 100. Served as the Principal-in-Charge of the largest and most significant engineering projects undertaken by the Company. Duties included extensive experience in wastewater management planning through development of EPA Section 201 facility plans. Work also included EPA Section 208 Water Quality planning. Responsible for litigation support, data evaluation, technical review, and direct technical staff oversight, and extensive community relations matters. Responsible for the overall management of all environmental services provided in the western U.S. through five regional offices. He has had extensive experience with mill tailings removal programs, having been the Principal-in-Charge for the ARIX Corporation for the Grand Junction Remedial Action Program (GJRAP) and the UMTRAP Program. These two programs involved the expenditure of over $100 million and consisted of repetitive removal actions at several thousand different locations. Mr. Windolph's special project achievements include the completion of the first approved Regional Water Quality Management Plan in the U.S., and the receipt by the ARIX Corporation of the "Grand Award" for design excellence given in a national competition sponsored by the American Consulting Engineers Council.

Relevant Project Experience:

- *Rico Site Technical Support for VCUP Application*: Mr. Windolph served as Lead Engineer in the preparation of a conceptual remediation plan (including Environmental Assessment, Risk Assessment, Remedial Design, Field Sampling and Analysis and Preparation of the Application) to be submitted to the State of Colorado under the Colorado Voluntary Cleanup and Redevelopment Act for the Rico Mining District site area. Responsible for preparing the complete application and assist client in obtaining approval of the plan from the State of Colorado, final design, and preparation of construction documents.

- *Assist the city of Commerce City, CO. in the analysis of the proposed remediation plan for the Rocky Mountain Arsenal.* Served as Principal-in-Charge of an evaluation of the alternatives under consideration for the Rocky Mountain Arsenal and their effects on Commerce City.

- *Warm Springs Ponds Active Area Operable Unit, Silver Bow Creek/Butte Area CERCLA Site, Montana.* Mr. Windolph served as a supervising engineer assisting the design staff in the preparation of contract and bidding documents, plans, and specifications for initial phases of the Warm Springs Ponds remediation program. He also served as the Project Manager and lead technical engineer for Remedial Action construction oversight during removal actions at this superfund site. He directed technical staff, reviewed data reports for submittal to PRP and EPA, and provided negotiations support. He was responsible for compliance with the Construction Quality Assurance Plan (CQAP) and the Site Health and Safety Plan. Mr. Windolph also assisted PRP in preparation of Remedial Action monthly construction progress reports. He provided technical oversite and management for design and preparation of construction plans and specifications, including direction of staff and subconsultants and prepared detailed construction cost estimates for each phase of remediation.

- ***Warm Springs Ponds Inactive Area Operable Unit, Silver Bow Creek/Butte Area CERCLA Site, Montana.*** Mr. Windolph served as Project Manager for the Feasibility Study on this superfund site. He assisted in the development of Media Specific Actions, alternative Remedial Actions from Media Specific Actions, and provided negotiations support for the preferred alternative.

- ***Rocky Mountain Arsenal Basin F Investigations, Denver.*** Principal directing engineering staff and QA/QC for treatability study of chemical solidification as an alternative for decontamination of Basin F. Included process evaluation and selection, preliminary Remedial Design, equipment selection, and preparation of estimates for capital and operation and maintenance costs. A separate project involved preparation of Remedial Design for pilot scale test burn incineration of Basin F contents.

- ***Bellevue Water Treatment Plant Renovation for City of Greeley, Colorado.*** Vice President in Charge of Planning for design and construction of improvements to upgrade facility to meet new drinking water standards. Included chemical addition, flocculation, sedimentation, mixed media filtration, and modernizing of instrumentation.

- ***201 Wastewater Facilities.*** Responsibilities included land use planning, planning area delineation, population projects, flow projections, alternative identification, public participation, preliminary design, and cost estimating and analysis for numerous projects in the Rocky Mountain Region.

- ***12 MGD Land Application Wastewater Treatment Facility Project Planning for City of Greeley, CO.*** Direct technical staff for a 201 Facilities plan amendment involving preliminary design of pumping, transmission, aerated lagoon treatment, storage, and pivot sprinkler irrigation for crop production using treated wastewater. Project involved extensive public participation needs and water rights considerations.

TITAN ENVIRONMENTAL

PAUL D. BERGSTROM
Risk Assessment Manager

EDUCATION:

M.S., Microbiology, Colorado State University, 1971
B.S., Environmental Chemistry/Microbiology, Colorado State University, 1967

EXPERTISE:

- Twenty-five years of government and industry experience in the development and management of diversified environmental regulatory compliance and permitting programs
- Director of all environmental health studies and risk assessments for ARCO's Rocky Mountain Environmental Remediation Group targeted at the remediation of Superfund mining sites
- Environmental Manager for ARCO Coal Company and Anaconda Minerals Company; responsible for management of air, water, hazardous waste and reclamation permitting and compliance programs in support of the acquisition and operation of oil shale facilities, underground and surface coal mines, and the divestiture, closure and remediation of nonoperating mining facilities, including numerous Superfund sites
- Managed all preparation of industry and government environmental impact statements for the U.S. Environmental Protection Agency (EPA), Region VI
- Served as the technical coordinator in negotiations and settlement agreements with regulatory agencies

REPRESENTATIVE PROJECT EXPERIENCE:

Directed the investigation of arsenic and lead environmental health exposure studies at two major Superfund mining and smelter sites in Montana. The results of these studies provided the basis for the adoption of site-specific exposure factors in lieu of default factors used by the EPA to calculate risk to human health. As a result, low-cost alternative remedies for site cleanup were instituted.

Managed the closure of a major uranium mill in New Mexico resulting in Nuclear Regulatory Commission licensing approval for decommissioning of mill facilities, tailings reclamation, implementation of a ground water corrective action plan and initial acceptance of an alternate concentration limit for uranium.

Developed and implemented a remedial action plan under the Arizona Superfund Program for tailings stabilization, ground water monitoring and long-term maintenance of a lead/zinc smelter site in Arizona.

Managed the closure of a major minerals research facility in Arizona, including hazardous waste disposal, closure of the TSD facility and ground water monitoring wells, asbestos abatement and removal, compliance monitoring of the community water system and its transfer to local government.

Performed environmental site assessments on numerous mining-related properties destined for commercial real estate transactions.

Managed the conduct of environmental baseline studies under the Office of Surface Mining and state permitting programs required to construct and operate surface and underground coal mines in Wyoming, Colorado and Utah.

Developed a comprehensive environmental protection plan that was approved by the Indonesian Government for the construction of a surface coal mine.

Managed the development and implementation of a landfarm designed to treat underground coal gasification polynuclear aromatic hydrocarbon wastes in Wyoming.

Provided technical litigation support to counsel defending clients on environmental legislative and regulatory issues.

PROFESSIONAL AFFILIATIONS:

Society of Environmental Geochemistry and Health
American Chemical Society
American Public Health Association
Society of Microbiology
Society of Sigma XI

PUBLICATIONS AND PRESENTATIONS:

Author and co-author of numerous journal articles reporting the results of environmental health risk assessment studies conducted at Superfund mining sites. Numerous presentations to regulatory agencies, professional societies and the public.

CERTIFICATIONS:

40 Hour OSHA Health and Safety Training with 8-Hour Annual Refresher in compliance with 29 CFR 1910.120
Supervisor Safety Training for Hazardous Waste Operations

SUZANNE I. HARTLEY
Toxicologist

EDUCATION:

M.S., Environmental Toxicology, University of Minnesota, 1988
B.S., Communication Disorders, University of Minnesota, 1983

EXPERTISE:

- Over seven years of experience in the fields of risk assessment, toxicology, environmental assessment, hazardous waste management, and data analysis
- Provided risk assessment support for remedial investigations, designed technical approaches used to estimate allowable exposure limits of pollutants to protect the public health and the environment, and designed and implemented sampling and analysis plans for risk assessment and remedial investigation purposes
- Served as the corporate health and safety officer for an environmental consulting firm
- Provided statistical analysis of chemical data for use in risk assessments
- Provided technical support in the development of toxicity profiles
- Reviewed RCRA landfill permit applications

REPRESENTATIVE PROJECT EXPERIENCE:

Kellogg Smelter, Idaho. Responsible for risk assessment and public health issues for evaluation of heavy metals exposure to residents living near a large mining/smelter site in Kellogg, Idaho. Worked closely with the State of Idaho Health Department to implement community programs aimed at reducing lead exposure in children. Designed and implemented a house-dust sampling program for residents living near the site. These results assisted with speculation analysis and defining the extent of contamination at the site.

Montana Pole Site, Butte, Montana. Conducted a baseline human health risk assessment on the presence of PCBs and metals in soils, ground water, and surface water for the State of Montana. Worked closely with the state to determine the extent of contamination at the site.

Butte Soils, Butte, Montana. Conducted a comprehensive risk assessment for the residential soils near a mining site located in Butte. The risk assessment evaluated approximately 200 soil samples and site-specific exposure scenarios including ingestion of home-grown vegetables, inhalation of dust by children while dirt-bike riding on tailings piles, and ingestion of soil.

White Pine, Michigan - Assisted client with design and implementation of a sampling and analysis plan for the purposes of investigating the potential presence of hazardous waste. Reviewed and analyzed data for over 200 samples collected for the investigation. Conducted a site-specific health risk assessment based on data collected on-site. Evaluated industrial exposures to metals in soils and ground water.

Agency for Toxic Substances and Disease Registry (ATSDR).
Assisted with a comprehensive literature review and compilation of data for development of toxicity profiles for the Agency of Toxic Substances and Disease Registry (ATSDR).

PROFESSIONAL AFFILIATIONS:

Society of Toxicology and Environmental Chemistry (SETAC)
Rocky Mountain Chapter for the Society of Risk Analysis

CERTIFICATIONS:

40 Hour OSHA Health and Safety Training with 8-Hour Annual Refresher in compliance with 29 CFR 1910.120
Supervisor Safety Training for Hazardous Waste Operations (1995)
EPA Seminar on Conducting CERCLA Site Risk Assessments (1992)
First Aid and CPR Certification (1995)

APPENDIX B

SMALL SITE ACTIVITIES

Possible Small Site Activities

ARCO Rico Cleanup Project

April 4, 1996

DRAFT

ATLANTIC CABLE MINE HISTORICAL SITE

ATLANTIC CABLE MINE HISTORICAL SITE

Site Information

- Ownership: Rico Properties, LLC; owns the Atlantic Cable headframe area and undeveloped commercial land to the north bordering Glasgow Avenue (Highway 145). The site is bordered by an alley easement to the west and Soda Street to the south.

- Rico Properties is in discussion with the local fire district concerning transfer of a 75 to 100-ft wide and 100-ft long portion of this site to the fire district for location of a new fire station. The portion of this site under discussion is immediately north of the headframe.

- The headframe structure is in disrepair and although a portion has been adequately fenced, a platform with deteriorating floor and overhead beams is accessible to foot traffic on it's west side.

- Surface material around the headframe and the commercial property to the north contains fine to coarse fragments of sulfide-bearing limestone and, in a few small patches, abundant dark-colored specularite-chlorite rocks. These materials are mine wasterock, although the Atlantic Cable Shaft was originally sunk on outcropping mineralization.

- The area around the headframe and the commercial area to the north (especially where the fire station may be located) has bare, rocky surfaces. Moderate-size aspen have revegetated this north part of the site and small clumps of Aspen have started in a grassy area bordering Soda Street.

Site Activities Acceptable to the Owner

- Slopes along Silver Creek and site south of Silver Creek can be covered with growth media and revegetated with grasses as appropriate.

- Development of picnic area (placement of picnic table, removal of small cement slab, thinning of existing aspen, enhanced grassy area) on south side of Silver Creek.

- Attractive (Victorian-style) iron protection fence around outside base of Atlantic Cable headframe structure.

- Fill and grading of 75 to 100-ft wide and 100-ft long potential fire station area. Fill should be appropriate for future building construction. Slope to west needs to anticipate entry to fire station from alley easement.

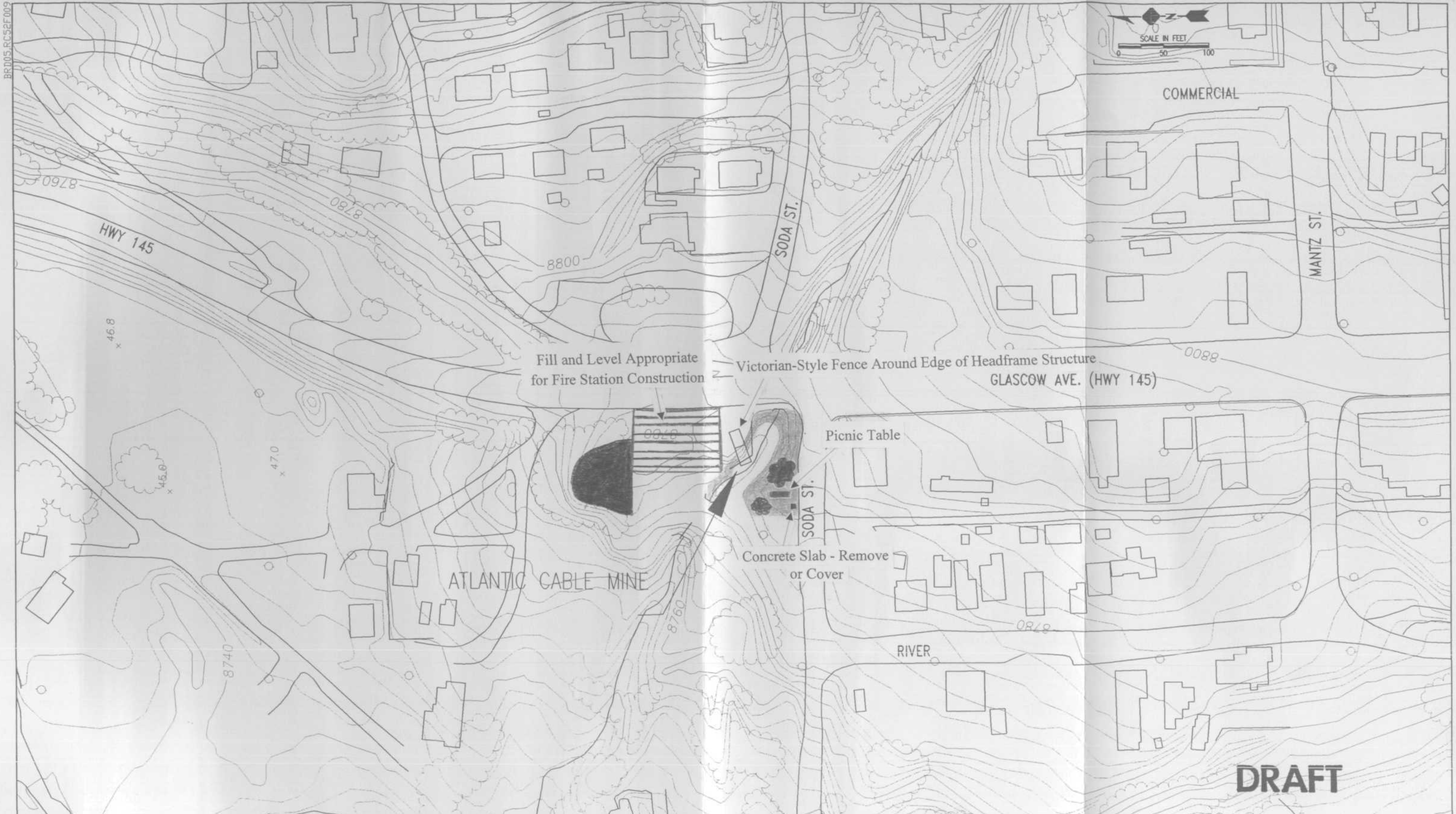
- Growth media cover and revegetation on bare areas only on north side of site (as at Grand View Smelter). Trees need to be preserved.

Future Use

- Historical preservation site (headframe and nearby picnic area).
- Community facilities such as fire station.
- Commercial.

DRAFT

Atlantic Cable Mine Historical Site



Enhance/add soil cover; seed for "lawn" grass on flat surfaces; seed for native grasses on slopes. Thin but leave trees.

Cover and revegetate bare areas as at Grand View Smelter.

ATLANTIC RICHFIELD COMPANY
RICO SITE TECHNICAL SUPPORT

ATLANTIC CABLE MINE

10

SHAMROCK MINE EAST WASTEROCK DUMP

SHAMROCK MINE EAST WASTEROCK DUMP

Site Information

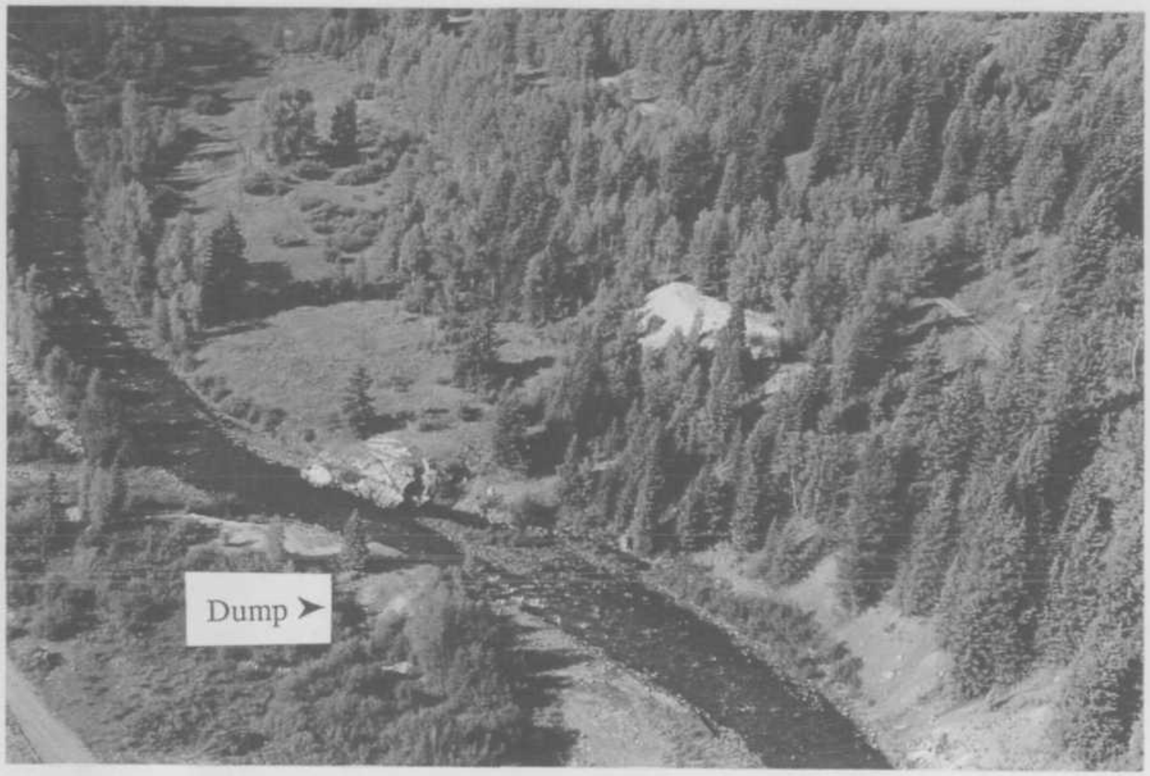
- Property ownership: Rico Properties, LLC.
- The site is a wasterock dump from the Shamrock Mine. This mine is located on the east side of the Dolores River but a trestle or tram transported ore and wasterock across to the east side of the river.
- The Shamrock dump is a 3 x 50 x 300-ft pile of limestone-rich wasterock on the east bank of the Dolores River. Some sulfide minerals including galena are visible in the fine to coarse rock fragments. A small area of specularite-rich material is present along the river bank.
- The surface of this dump is mostly bare but small aspen trees and willows have started to revegetate this area.

Site Activities Acceptable to Owner

- Remove wasterock and consolidate at Columbia tailings.
- Preserve as many trees as possible.
- Reseed as at other removal areas.

Future Use

- Open-space in the Dolores River Corridor.



Shamrock Mine East Waterock Dump

Limestone - Rich Wasterock

Specularite - Rich Area

ATLANTIC RICHFIELD COMPANY
RICO SITE TECHNICAL SUPPORT

SHAMROCK DUMP

VAN WINKLE MINE HISTORICAL SITE

VAN WINKLE MINE HISTORICAL SITE

Site Information

- Land ownership: Rico Properties, LLC; owns headframe area and intervening lands between headframe and Garfield Street. This is about the north one-third of dump. South two-thirds of dump has other owners and is not being addressed by these activities.

- Headframe area has existing chain link fence but gate is open.

- Site is limestone-rich wasterock dump with visible sulfide minerals including galena. Materials range from fine to coarse rock fragments with many megascopic examples of ore and gangue minerals.

- The surfaces of the dump are locally steep and mostly bare of vegetation.

Site Activities Acceptable to Owner

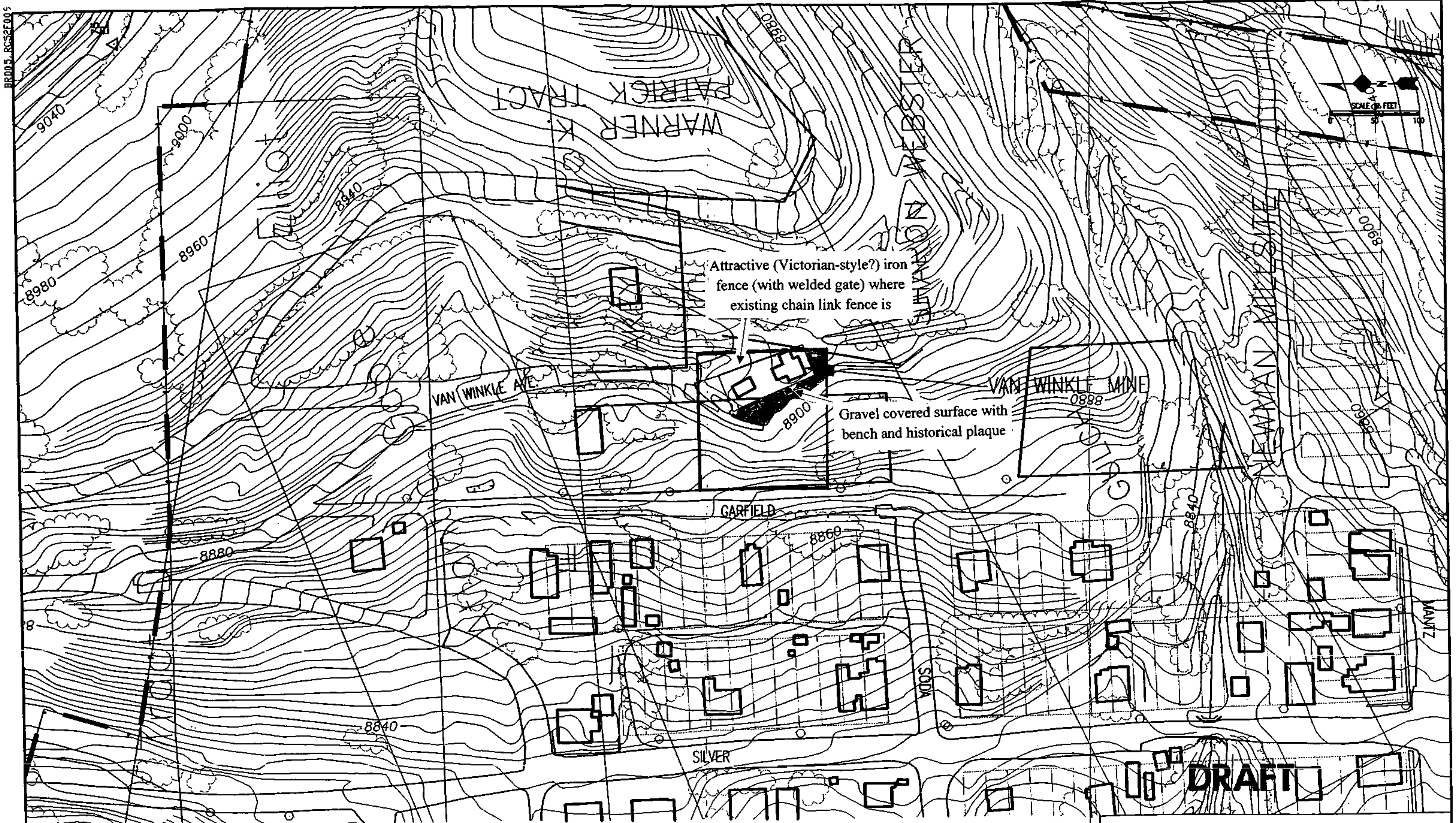
- Replace chain link fence with attractive (Victorian-style?) iron fence. Fence should have gate but it should be permanently closed (welded).

- Cover upper level area around south and west side of headframe with crushed rock or gravel. This area can have a bench and historical plaque for visitors.

Future Use

- The portion of the area addressed by these activities would be preserved as an open-space historical site.

Van Winkle Mine Historical Site (Center)



ATLANTIC RICHFIELD COMPANY
RICO SITE TECHNICAL SUPPORT

VAN WINKLE MINE

16

RC52F766

RIO GRANDE SOUTHERN COALING FACILITY
(PASADENA SMELTER)

RIO GRANDE SOUTHERN COALING FACILITY (PASADENA SMELTER)

Site Information

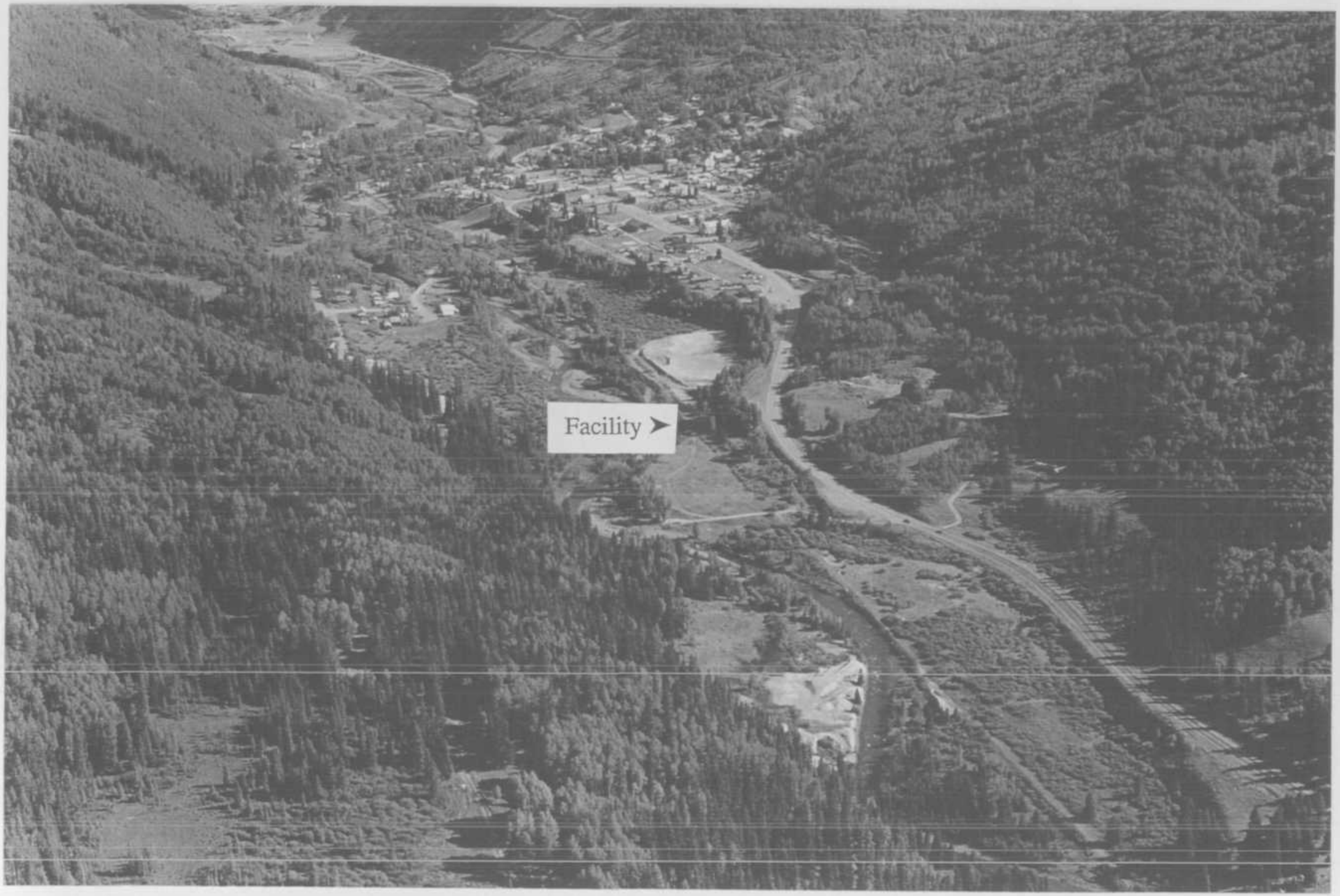
- Land ownership; Rico Properties, LLC; entire site is on Rico Smelting Company tract.
- Site is on 50-ft high bank between Dolores River and Highway 145. Rio Grande Southern grade is adjacent to Dolores River on site and the river is eroding into railroad grade at this location.
- Grade for old road or railroad spur transects site about two-thirds of the way upslope from river.
- Site is heavily vegetated with large aspen and intermediate-size spruce. Owner wants to preserve as many trees as possible.
- Site was location of coaling facility for Rio Grande Southern Railroad.
- Slag(?) and black cinder/coke/coal-bearing material exposed at surface on both sides of railroad grade.

Site Activities Acceptable to Owner

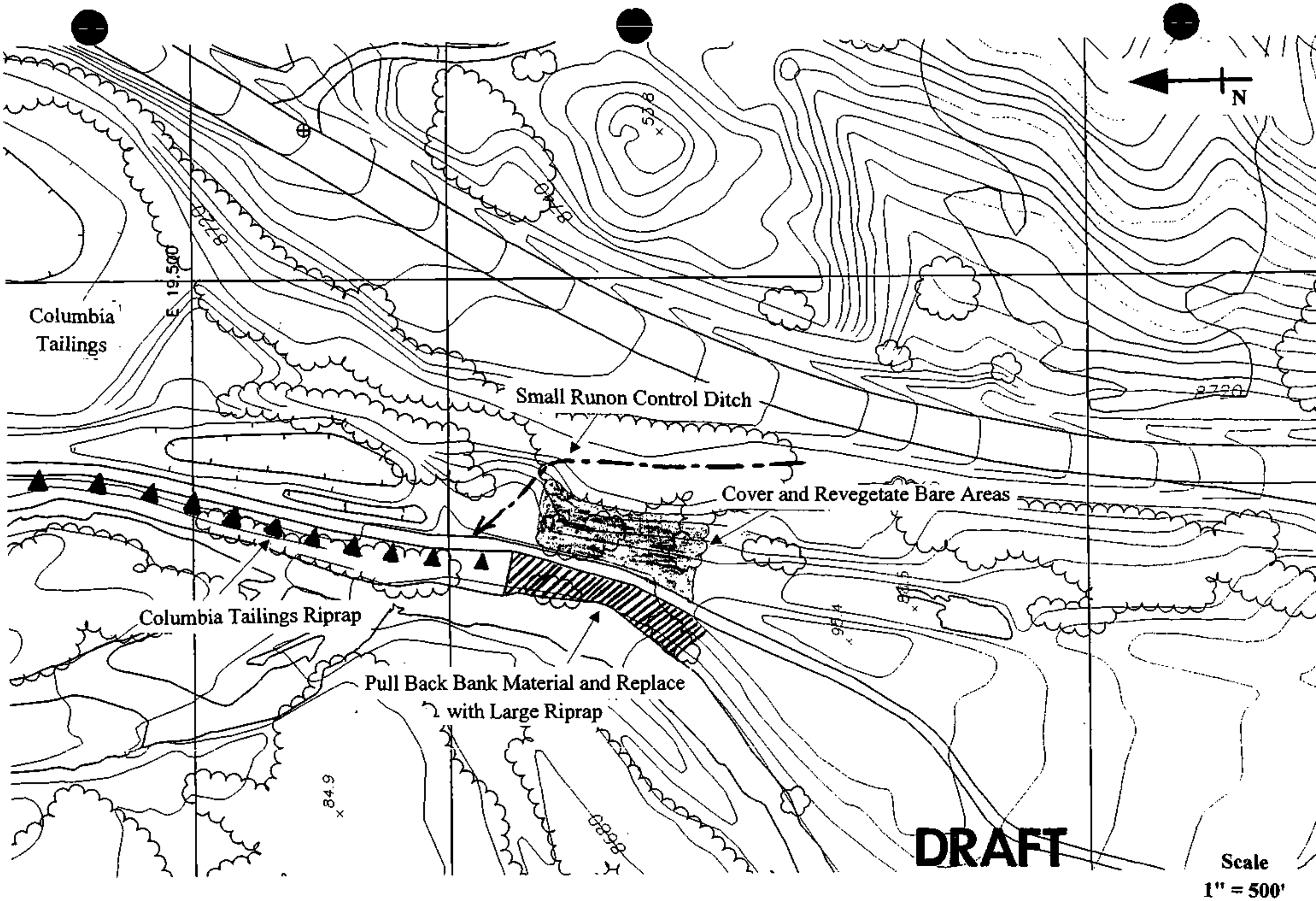
- Remove slag(?)-bearing material adjacent to river (between river and railroad grade) and replace with appropriate size riprap.
- Material removed can be consolidated with Columbia tailings.
- Riprap should be continuous with that of Columbia tailings site.
- Cover and revegetate (as at Grand View Smelter site) bare areas on east side of railroad grade.
- Leave as many trees undisturbed as possible.
- A small runon control ditch can be placed on old road grade transecting site if appropriate.
- Water collected by this ditch can be routed to Columbia tailings runon control system.

Future Use

- Site should be integrated into Columbia tailings open space/river corridor plan.



Rico Grande Southern Coaling Facility



RIO GRANDE SOUTHERN COALING FACILITY

APPENDIX C

STATISTICAL ANALYSES

APPENDIX C
STATISTICAL ANALYSES

The conclusion that the means are equal (similar) between two areas is the acceptance of the "null hypothesis" ($H_o: h_1 = h_2$) at a given significance level. The acceptance of the null hypothesis also means that the test was "passed". If the test "failed", then the null hypothesis was rejected and the means were different.

The significance level represents the risk of falsely rejecting the null hypothesis, thus falsely concluding that the means are different. The statistical tests for this study were conducted at a significance level of 5%. This means there is a 5% chance of falsely concluding that the means are different and that the sample concentrations in the two areas are statistically different, thus indicating a difference in impacts from the former smelter stack emissions.

A T-test calculation was also completed to compare the means of each data set. A two-sample T-test for independent samples was used.

The test statistic (λ) was calculated as follows:

$$\lambda = x - y/(s_1^2/n_1 - s_2^2/n_2)^{1/2}$$

The degrees of freedom was calculated as follows:

$$df = (s_1^2/n_1 - s_2^2/n_2)^2/(s_1^2/n_1)^2/(n_1-1) + (s_2^2/n_2)^2/(n_2-1)$$

The test statistic was then compared to the appropriate tabulated T statistics. The tabulated T statistic was determined by using the degrees of freedom calculated as above and 5% ($1-\alpha/2$) significance level. If $\lambda \geq t_{d,1-\alpha/2}$ or $\lambda < -t_{d,1-\alpha/2}$, then the null hypothesis is rejected and the means are not equal. If $-t_{d,1-\alpha/2} < \lambda\ t_{d,1-\alpha/2}$, then the null hypothesis is accepted and the means are considered equal.

APPENDIX D

CARCINOGENIC AND NONCARCINOGENIC ALGORITHMS

CARCINOGENIC RISK

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Residents at North Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where:

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**5.69E-07**	**1.33E-06**
CS = Chemical Concentration in Soil or Dust (mg/kg)[1]	20	20
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **1.90E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **2.84E-06**

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Residents at South Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.22E-06**	**2.84E-06**
CS = Chemical Concentration in Soil (mg/kg)	43	43
IR = Ingestion Rate (mg/day)	100	200
CF = Conversion Factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25550	25550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **4.05E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **6.08E-06**

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[1] Concentration is 95% UCL of the mean As concentration.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Residents at North Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**9.73E-07**	**2.27E-06**
CS = Chemical Concentration in Soil (mg/kg)	34	34
IR = Ingestion Rate (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **3.24E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **4.87E-06**

[1] Concentration is 95% UCL of the mean As concentration.

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RICO COMMUNITY SOILS
Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Residents at South Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**8.06E-07**	**1.88E-06**
CS = Chemical Concentration in Soil (mg/kg)	29	29
IR = Ingestion Rate (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1 00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0 45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **2.69E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **4.03E-06**

---

[1] Concentration is 95% UCL of the mean As concentration.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Future Residents at East Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**7.13E-07**	**1.66E-06**
CS = Chemical Concentration in Soil (mg/kg)	25	25
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **2.38E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **3.56E-06**

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[1] Concentration is 95% UCL of the mean As concentration.

RICO COMMUNITY SOILS
Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Future Residents at West Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**9.34E-07**	**2.18E-06**
CS = Chemical Concentration in Soil (mg/kg)	33	33
IR = Ingestion Rate (mg/day)	100	200
CF = Conversion factor (10^{-6} kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **3.11E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **4.67E-06**

[1] Concentration is 95% UCL of the mean As concentration.

RICO COMMUNITY SOILS
Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Residents on Silver Creek Alluvium

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where:

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**9.90E-07**	**2.31E-06**
CS = Chemical Concentration in Soil (mg/kg) [1]	35	35
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic	1.50	1.50

Total CDI **3.30E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **4.95E-06**

[1] Concentration is 95% UCL of the mean As concentration.

CRNOSOIL XLS3/29/96

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Future Residents of the Grand View Smelter Area

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.01E-06**	**4.69E-06**
CS = Chemical Concentration in Soil or Dust (mg/kg)[1]	71	71
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Dust (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25550	25550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **6.70E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **1.00E-05**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS
Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Recreational Visitors at the River Corridor

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.64E-07**	**8.48E-07**
CS = Chemical Concentration in Soil (mg/kg)	46	46
IR = Ingestion Rate (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	72	72
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **1.21E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **1.82E-06**

[1] Concentration is 95% UCL of the mean As concentration.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Soil Ingestion by Recreational Visitors at Waste Rock Areas

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**4.38E-07**	**1.02E-06**
CS = Chemical Concentration in Soil (mg/kg)	55	55
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	72	72
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic	1.50	1.50

Total CDI **1.46E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **2.19E-06**

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Residents at North Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**4.93E-07**	**1.15E-06**
CS = Chemical Concentration in Dust (mg/kg)[1]	7.4	7.4
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Dust (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **1.64E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **2.47E-06**

[1]Arsenic concentration in dust was calculated as follows: (0.43 x Mean As) + (0.1 x Mean As). See text.
Mean As = 16.7 mg/kg.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Residents at South Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**7.00E-07**	**1.63E-06**
CS = Chemical Concentration in Dust (mg/kg)[1]	10.50	10.50
IR = Ingestion Rate (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **2.33E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **3.50E-06**

[1]Concentration of arsenic in dust was calculated as follows: (43% x Mean As) + (10% x Mean As). See text

Mean As = 23.9 mg/kg

RICO COMMUNITY SOILS
Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Residents at North Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**8.13E-07**	**1.90E-06**
CS = Chemical Concentration in Dust (mg/kg)[1]	12	12
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic	1.50	1.50

Total CDI **2.71E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **4.07E-06**

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[1] Arsenic concentration in dust was calculated as follows: (0.43 x $Mean_{As}$ mg/kg) + (0.1 x $Mean_{As}$ mg/kg). See text
Mean As = 27.7 mg/kg

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Residents at South Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where:

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**6.66E-07**	**1.56E-06**
CS = Chemical Concentration in Soil (mg/kg)	10	10
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Dust (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic	1.50	1.50

Total CDI **2.22E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **3.33E-06**

[1]Arsenic concentration in dust was calculated as follows: (0.43 x $Mean_{As}$ mg/kg) + (0.1 x $Mean_{As}$ mg/kg). See text.
Mean As = 22.8 mg/kg

RICO COMMUNITY SOILS
Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Future Residents at East Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**5.93E-07**	**1.38E-06**
CS = Chemical Concentration in Soil or Dust (mg/kg)[1]	8.9	8.9
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25550	25550
CSF_{As} = Cancer Slope Factor for Arsenic	1.50	1.50

Total CDI **1.98E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **2.97E-06**

[1] Concentration of arsenic in dust was calculated as follows: (0.43 x Mean As) + (0.1 x Mean As)
Mean As = 20.2 mg/kg

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Future Residents at West Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**8.53E-07**	**1.99E-06**
CS = Chemical Concentration in Soil or Dust (mg/kg)[1]	13	13
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25550	25550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **2.84E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **4.27E-06**

[1]Concentration of arsenic in dust was calculated as follows: (0.43 x Mean As) + (0.1 x Mean As). See text.
Mean As = 29 mg/kg

RICO COMMUNITY SOILS
Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Residents on Silver Creek Alluvium

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**4.69E-07**	**1.09E-06**
CS = Chemical Concentration in Dust (mg/kg)[1]	7.0	7.0
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25,550	25,550
CSF_{As} = Cancer Slope Factor for Arsenic	1.50	1.50

Total CDI **1.56E-06**

$Risk_{As}$ = Total CDI x CSF_{As} **2.35E-06**

[1]Arsenic concentration in dust was calculated as follows: (0.43 x $Mean_{As}$ mg/kg) + (0.1 x $Mean_{As}$ mg/kg). See text.
Mean As = 16 mg/kg

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Future Residents of the Grand View Smelter Area

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.23E-06**	**2.88E-06**
CS = Chemical Concentration in Soil or Dust (mg/kg)[1]	19	19
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Dust (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25550	25550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **4.11E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **6.16E-06**

[1]Concentration of arsenic in dust was calculated as follows: (0.43 x Mean As) + (0.1 x Mean As). See text.

Mean As = 42 mg/kg

RICO COMMUNITY SOILS
Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Recreational Visitors at the River Corridor

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.02E-06**	**2.38E-06**
CS = Chemical Concentration in Soil or Dust (mg/kg)[1]	15	15
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Dust (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25550	25550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **3.40E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **5.10E-06**

[1]Concentration of arsenic in dust was calculated as follows: (0.43 x Mean As) + (0.1 x Mean As). See text.

Mean As = 34.7 mg/kg

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Carcinogenic Algorithm for Dust Ingestion by Recreational Visitors at the Waste Rock Areas

$CDI = (CS \times IR \times CF \times FI \times EF \times ED \times BAF) / (BW \times AT)$

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**9.40E-07**	**2.19E-06**
CS = Chemical Concentration in Soil or Dust (mg/kg)[1]	14	14
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Dust (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	25550	25550
CSF_{As} = Cancer Slope Factor for Arsenic $(mg/kg/day)^{-1}$	1.50	1.50

Total CDI **3.13E-06**

$Risk_{As}$ = (Total CDI x CSF_{As}) **4.70E-06**

[1]Concentration of arsenic in dust was calculated as follows: (0.43 x Mean As) + (0.1 x Mean As). See text.
Mean As = 32 mg/kg

Cancer Risks from Soil Ingestion and Dust Inhalation for Dirt Bike Riders Based based on Roadfill Data

$$CR = C_s \times (EF \times ED) \times [(IR_s \times CF_s \times SF_o \times BAF_s) + (IR \times SF_i \times DL \times ET)]/(BW \times AT)$$

where,

C_{As} = 95% UCL on As concentration in Roadfill	**30**
CR = Carcinogenic Risk	
AT = Averaging time (days)	25,550
CF = Conversion factor (kg/mg)	1.00E-06
SF_o = Arsenic Cancer Slope Factor (oral) $(mg/kg\text{-}day)^{-1}$	1.5
SF_i = Arsenic Cancer Slope Factor (inhalation) $(mg/kg\text{-}day)^{-1}$	15
EF = Exposure Frequency (days/year)	72
ED = Exposure Duration (years)	30
BAF = Bioavailability of Soil (unitless)	0.18
BW = Body Weight (kg)	70
IR_s = Ingestion Rate (soil) (mg/day)	100
IR = Inhalation Rate (m^3/hour)	2.5
DL = Dust Loading Factor (kg/m^3)	3.80E-07
ET = Exposure Time (hours/day)	5

Cancer Risk due to Arsenic **3.56E-06**

NONCARCINOGENIC RISKS

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Residents at North Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.66E-06**	**1.55E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	20.1	20.1
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **1.71E-05**

HQ_{As} = Total CDI / RfD **5.71E-02**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Residents at South Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.55E-06**	**3.31E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	43	43
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0 0003

Total CDI	**3.67E-05**
HQ_{As} = Total CDI / RfD	**1.22E-01**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Residents at North Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.84E-06**	**2.65E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	34	34
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6} kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **2.93E-05**

HQ_{As} = Total CDI / RfD **9.78E-02**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS
Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Residents at South Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.35E-06**	**2.20E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	29	29
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **2.43E-05**

HQ_{As} = Total CDI / RfD **8.11E-02**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Future Residents at East Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.08E-06**	**1.94E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	25	25
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **2.15E-05**

HQ_{As} = Total CDI / RfD **7.16E-02**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Future Residents at West Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.72E-06**	**2.54E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	33	33
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfDAs = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI	**2.81E-05**
HQ_{As} = Total CDI / RfD	**9.38E-02**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Residents on Silver Creek Alluvium

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.89E-06**	**2.70E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	35	35
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **2.98E-05**

HQ_{As} = Total CDI / RfD **9.95E-02**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Future Residents at the Grand View Smelter Area

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**5.86E-06**	**5.47E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	71	71
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **6.05E-05**

HQ_{As} = Total CDI / RfD **2.02E-01**

[1] Arsenic concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion in the Dolores River Corridor Recreational Area

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.07E-06**	**9.96E-06**
CS = Chemical Concentration in Soil (mg/kg)[1]	46	46
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	72	72
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **1.10E-05**

HQ_{Mn} = Total CDI / RfD **3.68E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion for Recreational Visitors at the Waste Rock Areas

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.28E-06**	**1.19E-05**
CS = Chemical Concentration in Soil (mg/kg)[1]	55	55
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	72	72
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.183	0.183
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **1.32E-05**

HQ_{Mn} = Total CDI / RfD **4.40E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion for Dirt Bike Riders based on Roadfill Data

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult
CDI = Chronic Daily Intake (mg/kg-day)	**6.85E-07**
CS = Chemical Concentration in Dust (mg/kg)[1]	30
IR = Ingestion Rate (mg/day)	100
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45
EF = Exposure Frequency (days/year)	72
ED = Exposure Duration (years)	30
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.18
BW = Body Weight (kg)	70
AT = Averaging Time (days)	10,950
RfD = Oral Reference Dose (mg/kg/day)	0.0003

CDI **6.85E-07**

HQ_{As} = CDI / RfD **2.28E-03**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 5095 mg/kg.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Residents at North Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	1.43E-06	1.33E-05
CS = Chemical Concentration in Dust (mg/kg)[1]	7.4	7.4
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **1.48E-05**

HQ_{As} = Total CDI / RfD **4.92E-02**

[1] Arsenic concentration in dust was calculated as follows: (43% x Mean As) + (1% x Mean As). See text.
Mean As = 16.7 mg/kg.

RICO COMMUNITY SOILS
Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Residents at South Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.04E-06**	**1.90E-05**
CS = Chemical Concentration in Dust (mg/kg)[1]	10.5	10.5
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **2.11E-05**

HQ_{As} = Total CDI / RfD **7.03E-02**

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[1] Arsenic concentration in dust was calculated as follows: (43% x Mean As) + (1% x Mean As). See text.
Mean As = 23.9 mg/kg.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Residents at North Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.37E-06**	**2.21E-05**
CS = Chemical Concentration in Dust (mg/kg)[1]	12.2	12.2
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **2.45E-05**

HQ_{As} = Total CDI / RfD **8.16E-02**

[1] Arsenic concentration in dust was calculated as follows: (43% x Mean As) + (1% x Mean As). See text.
Mean As = 27.7 mg/kg.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Residents at South Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.95E-06**	**1.82E-05**
CS = Chemical Concentration in Dust (mg/kg)[1]	10.0	10.0
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **2.01E-05**

HQ_{As} = Total CDI / RfD **6.72E-02**

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[1] Arsenic concentration in dust was calculated as follows: (43% x Mean As) + (1% x Mean As). See text.
Mean As = 22.8 mg/kg.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Future Residents at East Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.73E-06**	**1.61E-05**
CS = Chemical Concentration in Dust (mg/kg)[1]	8.9	8.9
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **1.79E-05**

HQ_{As} = Total CDI / RfD **5.95E-02**

[1] Arsenic concentration in dust was calculated as follows: (43% x Mean As) + (1% x Mean As). See text.
Mean As = 20.2 mg/kg.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Future Residents at West Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.48E-06**	**2.31E-05**
CS = Chemical Concentration in Dust (mg/kg)[1]	12.8	12.8
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0 258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0 0003	0.0003

Total CDI **2.56E-05**

HQ_{As} = Total CDI / RfD **8.54E-02**

[1] Arsenic concentration in dust was calculated as follows: (43% x Mean As) + (1% x Mean As). See text.
Mean As = 29 mg/kg.

RICO COMMUNITY SOILS

Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Residents on Silver Creek Alluvium

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**1.37E-06**	**1.28E-05**
CS = Chemical Concentration in Dust (mg/kg)[1]	7.0	7.0
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **1.41E-05**

HQ_{As} = Total CDI / RfD **4.71E-02**

[1] Arsenic concentration in dust was calculated as follows: (43% x Mean As) + (1% x Mean As). See text.
Mean As = 16 mg/kg.

RICO COMMUNITY SOILS
Arsenic Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Future Residents at the Grand View Smelter Area

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.60E-06**	**3.36E-05**
CS = Chemical Concentration in Dust (mg/kg)[1]	18.5	18.5
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.258	0.258
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{As} = Oral Reference Dose (mg/kg/day)	0.0003	0.0003

Total CDI **3.72E-05**

HQ_{As} = Total CDI / RfD **1.24E-01**

[1] Arsenic concentration in dust was calculated as follows: (43% x Mean As) + (1% x Mean As). See text.
Mean As = 42 mg/kg.

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RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Residents at North Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**8.15E-04**	7.61E-03
CS = Chemical Concentration in Soil (mg/kg)[1]	3616	3616
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **8.42E-03**

HQ_{Mn} = Total CDI / RfD **6.02E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Residents at South Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**5.72E-04**	**5.34E-03**
CS = Chemical Concentration in Soil (mg/kg)[1]	2536	2536
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **5.91E-03**

HQ_{Mn} = Total CDI / RfD **4.22E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Current Residents at North Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**5.75E-04**	**5.37E-03**
CS = Chemical Concentration in Soil (mg/kg)[1]	2552	2552
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **5.95E-03**

HQ_{Mn} = Total CDI / RfD **4.25E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS
Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Current Residents at South Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**5.65E-04**	**5.28E-03**
CS = Chemical Concentration in Soil (mg/kg)[1]	2508	2508
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **5.84E-03**

HQ_{Mn} = Total CDI / RfD **4.17E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Future Residents at East Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**7.82E-04**	**7.30E-03**
CS = Chemical Concentration in Soil (mg/kg)[1]	3469	3469
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **8.08E-03**

HQ_{Mn} = Total CDI / RfD **5.77E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS
Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Future Residents at West Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**4.08E-04**	**3.81E-03**
CS = Chemical Concentration in Soil (mg/kg)[1]	1810	1810
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **4.22E-03**

HQ_{Mn} = Total CDI / RfD **3.01E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Residents on Silver Creek Alluvium

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**7.93E-04**	**7.40E-03**
CS = Chemical Concentration in Soil (mg/kg)[1]	3516	3516
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **8.19E-03**

HQ_{Mn} = Total CDI / RfD **5.85E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion by Future Residents at the Grand View Smelter Area

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.28E-03**	**2.13E-02**
CS = Chemical Concentration in Soil (mg/kg)[1]	10120	10120
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	256	256
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **2.36E-02**

HQ_{Mn} = Total CDI / RfD **1.68E-01**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion in the Dolores River Corridor Recreational Area

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.27E-04**	**3.05E-03**
CS = Chemical Concentration in Soil (mg/kg)[1]	5162	5162
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	72	72
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **3.38E-03**

HQ_{Mn} = Total CDI / RfD **2.42E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion for Recreational Visitors at the Waste Rock Areas

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**5.54E-04**	**5.17E-03**
CS = Chemical Concentration in Soil (mg/kg)[1]	8739	8739
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45	0.45
EF = Exposure Frequency (days/year)	72	72
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **5.73E-03**

HQ_{Mn} = Total CDI / RfD **4.09E-02**

[1] Manganese concentration in soil is the 95% UCL of the mean concentration. See text.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Soil Ingestion for Dirt Bike Riders based on Roadfill Data

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult
CDI = Chronic Daily Intake (mg/kg-day)	**1.65E-04**
CS = Chemical Concentration in Dust (mg/kg)[1]	2596
IR = Ingestion Rage (mg/day)	100
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.45
EF = Exposure Frequency (days/year)	72
ED = Exposure Duration (years)	30
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50
BW = Body Weight (kg)	70
AT = Averaging Time (days)	10,950
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14

Total CDI	**1.65E-04**
HQ_{Mn} = Total CDI / RfD	**1.18E-03**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 5095 mg/kg.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Residents at North Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**4.05E-04**	**3.78E-03**
CS = Chemical Concentration in Dust (mg/kg)[1]	1074	1074
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **4.18E-03**

HQ_{Mn} = Total CDI / RfD **2.99E-02**

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[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 2,441 mg/kg.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Residents at South Rico (Background)

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.00E-04**	**2.80E-03**
CS = Chemical Concentration in Dust (mg/kg)[1]	796.4	796.4
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **3.10E-03**

HQ_{Mn} = Total CDI / RfD **2.21E-02**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 1810 mg/kg.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Current Residents at North Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.31E-04**	**3.09E-03**
CS = Chemical Concentration in Dust (mg/kg)[1]	879.6	879.6
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **3.42E-03**

HQ_{Mn} = Total CDI / RfD **2.45E-02**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 1,999 mg/kg.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Current Residents at South Rico

$$CDI = (CS \times IR \times CF \times FI \times EF \times ED \times BAF) / (BW \times AT)$$

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.11E-04**	**2.90E-03**
CS = Chemical Concentration in Dust (mg/kg)[1]	825.9	825.9
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **3.21E-03**

HQ_{Mn} = Total CDI / RfD **2.30E-02**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 1,877 mg/kg.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Future Residents at East Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.40E-04**	**3.18E-03**
CS = Chemical Concentration in Dust (mg/kg)[1]	903.8	903.8
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **3.52E-03**

HQ_{Mn} = Total CDI / RfD **2.51E-02**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 2,054 mg/kg.

RICO COMMUNITY SOILS
Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Future Residents at West Rico

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**2.33E-04**	**2.18E-03**
CS = Chemical Concentration in Dust (mg/kg)[1]	619.5	619.5
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **2.41E-03**

HQ_{Mn} = Total CDI / RfD **1.72E-02**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 1,408 mg/kg.

RICO COMMUNITY SOILS

Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Residents on Silver Creek Alluvium

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	Child
CDI = Chronic Daily Intake (mg/kg-day)	**3.81E-04**	**3.56E-03**
CS = Chemical Concentration in Dust (mg/kg)[1]	1012.0	1012.0
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI 3.94E-03

HQ_{Mn} = Total CDI / RfD **2.81E-02**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 2300 mg/kg.

RICO COMMUNITY SOILS
Manganese Chronic Daily Intake and Non-Carcinogenic Algorithm for Dust Ingestion by Future Residents at the Grand View Smelter Area

CDI = (CS x IR x CF x FI x EF x ED x BAF) / (BW x AT)

where,

	Adult	**Child**
CDI = Chronic Daily Intake (mg/kg-day)	**9.10E-04**	**8.49E-03**
CS = Chemical Concentration in Dust (mg/kg)[1]	2416	2416
IR = Ingestion Rage (mg/day)	100	200
CF = Conversion factor (10^{-6}kg/mg)	1.00E-06	1.00E-06
FI = Fraction Ingested from Contaminated Source (unitless)	0.55	0.55
EF = Exposure Frequency (days/year)	350	350
ED = Exposure Duration (years)	24	6
BAF = Bioavailability Factor for COPC in Soil (unitless)	0.50	0.50
BW = Body Weight (kg)	70	15
AT = Averaging Time (days)	8,760	2,190
RfD_{Mn} = Oral Reference Dose (mg/kg/day)	0.14	0.14

Total CDI **9.40E-03**

HQ_{Mn} = Total CDI / RfD **6.72E-02**

[1] Manganese concentration in dust was calculated as follows: (43% x Mean Mn) + (1% x Mean Mn). See text.
Mean Mn = 5,490mg/kg.

APPENDIX E

TOXICITY PROFILE

APPENDIX E
TOXICITY PROFILES

E.1 Arsenic

Arsenic is a naturally occurring element and is ubiquitous in the environment. The major source of occupational exposure to arsenic in the U.S. is in the manufacture of pesticides, herbicides and other agricultural products (Landrigan, 1981). High exposure to arsenic fumes and dust may also occur in the smelting industries. Because arsenic is present in mineral ores, it is found near mining sites as a byproduct of smelting. Inorganic and organic forms of arsenic have been widely used in pesticides and as a result, agricultural areas frequently have elevated concentrations of arsenic.

The primary transport mechanism of arsenic in the environment is via water. Most foods (meat and vegetables) contain some level of arsenic, but the daily diet in the U.S. contains below 0.04 mg. The diet may contain 0.2 mg per day if the diet contains seafood.

Arsenic exists as either the trivalent or hexavalent form. The particular form of arsenic ingested is a critical factor, since it is well established that trivalent arsenic compounds are more toxic than pentavalent forms. However, in both animal and humans, the pentavalent form is reduced to arsenite and the trivalent form is methylated to give the metabolites monomethylarsenic acid (MMA) and dimethylarsenic acid (DMA) (Vahter and Marafante, 1988). The pentavalent form is the most common at hazardous waste sites because natural oxidation processes in the environment favor this mineralogic formation (ATSDR, 1989).

Water-soluble arsenic is efficiently absorbed from the gastrointestinal tract (Tam et al., 1979). Excretion of absorbed arsenic is mainly via the urine. The biologic half-life of ingested inorganic arsenic is about ten hours and 50 to 80 percent is excreted in about 3 days. Reaching the systemic circulation, trivalent arsenic is detoxified in the liver by conversion to methylarsenic acid and dimethylarsenic acid, which are the principal forms excreted in the urine. The body burden of arsenic can reach considerable levels since it can be sequestered in nails, hair, bones, teeth, skin, liver, kidneys, and lungs (ATSDR, 1989).

At low concentrations, arsenic is not considered toxic and may be considered an essential nutrient and substitute for phosphorous in key biochemical reactions (ATSDR, 1989). At high levels, however, arsenic has been recognized as an effective human poison. At toxic levels, it produces a severe form of peripheral arteriosclerosis known as blackfoot disease. Oral ingestion of arsenic can effect the skin. Hyperkeratosis, hyperpigmentation, and hypopigmentation have been observed on the faces, necks, and backs of workers following chronic oral exposure (ATSDR 1991).

Chronic exposure to low levels of arsenic can result in malaise and fatigue, gastrointestinal distress, anemia and basophilic stippling and neuropathy. The prominent pathological effect, however, is plantar and palmar hyperpigmentation and hyperkeratotic lesions (ATSDR, 1989).

These lesions may ultimately develop into skin cancers and metastasize to other parts of the body.

Arsenic is a class A (known human) carcinogen based on observations of increased lung and skin cancer in human populations (EPA, 1995). The oral cancer slope factor for arsenic is 1.5 $(mg/kg\text{-}day)^{-1}$ and is based on a study by Tseng (1977). The study found significantly elevated standard mortality ratios for cancer of the bladder, lung, liver, kidney, skin and colon. Concentrations in the water ranged from 0.01 to 1.82 mg/L.

The oral reference dose is 3.0E-4 mg/kg-day based on a study by Tseng et al. (1968) and Tseng (1977). The data reported by Tseng show an increased incidence of blackfoot disease that increases with age and dose. Confidence in the oral RfD is medium due to the fact that doses were not well characterized and other contaminants were present.

The inhalation CSF is 15 $(mg/kg\text{-}day)^{-1}$ based on occupational exposure studies (Brown and Chu 1983a).

E.2 Lead

Lead is the most ubiquitous toxic metal and can be found in nearly all biologic systems. Because it is toxic to most living things at high doses and there is no biologic need, the major issue regarding lead is at what dose does it become toxic. Lead is commonly found at mining sites in the form of galena (PbS), cerussite ($PbCo_3$) and anglesite (PbSO4) ores (Beliles, 1975). Lead is also associated with the production and disposal and storage of batteries, antiknock fuel additives, and has been widely used for pigments in paints as well as glazes and coloring on ceramic pottery.

Lead content of food is variable, however, there are practically no lead-free food items. Other common sources of lead exposure include lead-based indoor paint, and lead in air from combustion of lead-containing auto exhausts or industrial emissions.

Age and nutritional factors greatly influence gastrointestinal absorption of lead. Absorption of lead in children is typically greater than in adults (ATSDR, 1990). High dietary levels of calcium and phosphorous can significantly reduce lead uptake while fasting increases the absorption of lead. Upon absorption, most lead is deposited in the bone matrix. The toxic effects of lead are due to interference with vital enzymes. Once lead is deposited in the bone matrix, excretion via the urine is very slow. The half-life of lead is approximately 20 years.

Acute effects of lead exposure include fatigue, sleep disturbances, constipation, anemia and neuritis. Chronic lead poisoning includes loss of appetite, metallic taste, constipation, anemia, pallor, malaise, weakness, insomnia, headache, irritability, muscle and joint pain, fine tremors, and damage to kidney tubules.

Indicators of lead exposure in children are blood enzyme level changes and neurobehavioral effects in children. Other signs of low-dose lead exposure include learning deficits and growth retardation in children and hypertension in middle-aged adults. Exposure to low doses of lead during childhood results in long-term effects which are thought to be irreversible. Lead exposure produces severe reproductive toxicity, including premature deliveries and spontaneous abortions in women and sterility in men.

Lead is classified as a B2 carcinogen by U.S. EPA based on kidney tumor data in animals. Because noncarcinogenic effects as a result of lead exposure may occur at levels so low that a threshold may not exist, the U.S. EPA considers it inappropriate to develop and RfD for lead. The U.S. EPA has not derived a reference dose or a cancer slope factor for lead.

E.3 Manganese

Manganese is an essential element and is a cofactor for a number of enzymatic reactions particularly those involved in phosphorylation, cholesterol and fatty acids synthesis. The principal source of manganese is food, although it is also present in urban air and water. Vegetables, fruits, grains, nuts, tea and some spices are rich in manganese (NAS, 1973; Underwood, 1977). Manganese and its compounds are used in making steel alloys, dry-cell batteries, electrical coils, ceramics, matches, glass, dyes, fertilizers, welding rods and as animal food additives.

Gastrointestinal absorption of manganese is less than 5 percent. Manganese is widely distributed in the body, however, it tends to concentrate in the pancreas, liver, kidney and intestines. The biologic half-life is 37 days. The principal route of excretion is the feces.

Acute exposure via inhalation results in manganese pneumonitis. Men working in plants with high concentrations of manganese dust show an incidence of respiratory disease 30 times greater than normal. Chronic exposure via inhalation (two years or more) results in effects to the central nervous system. Symptoms associated with chronic exposure to manganese include irritability, difficulty in walking, speech disturbances and compulsive behavior.

Manganese is classified as a class D carcinogen, not classifiable as to human carcinogenicity, and therefore, does not have a cancer slope factor. The oral reference dose recommended by EPA is 0.14 mg/kg/day..

APPENDIX F

CALCULATION OF DUST LOADING FACTOR

Appendix F

Calculation of Dust Loading Factor

A dust loading factor was estimated for use in evaluating exposures to dust for a dirt bike rider. The approach used was developed by Life Systems (1993) was adopted from the baseline risk assessment for Anaconda (CDM, 1995). A soil emission rate from dirt bike riding can be calculated using the following equation based on Cowherd et al. (1995):

$$E = 0.85 \times (S/10) \times (V/24)^{0.8} \times (W/7)^{0.3} \times (T/6)^{1.2}$$

Where:
$E = PM_{10}$ emission rate (kg/vehicle kilometer traveled (VKT)/hr)
S = Silt content of the soil (%)
V = Vehicle speed (km/hr)
W = Vehicle weight (Mg, where 1 Mg = 1,000 kg)
T = Number of tires (wheels) per vehicle

This equation calculates emission rates during the dirt-bike riding event. The values of the parameters above were derived as follows:

S — Silt content. A value of 20% was used, based on the range of silt % in clay soils presented in Buckman and Brady (1969). The percent of silt in clay soils such as that found in Colorado ranges from 0 to 40%, therefore 20% was selected as the average.

V — Vehicle Speed. The velocity of the dirt-bike riders was assumed to be 30 km/hr (about 20 mph).

W — Vehicle weight. The weight of the dirt-bikes was assumed to be about 50 kg. The weight of the rider was assumed to be 70 kg. The total weight is, therefore, 120 kg (0.12 Mg).

T — The number of tires per dirt bike is two.

Based on these parameters, the estimated Emission rate is 0.16 kg/VKT/hr. Multiplying by VKT and dividing by area yields the emission rate in units of $kg/hr/m^2$. The value of VKT is given by the number of bikes (assumed to be three) times the speed of each (30 km/hr). Dividing by 3,600 sec/hr results in an estimate of E of 2.0×10^{-8} $kg/sec/m^2$.

The concentration of PM_{10}s in air resulting from dirt-bike riding at each area were calculated using the estimated soil emission rate and a box model. The following formula was used (Hanna et al. 1982).

$$C = E \times X/(H/2 \times u)$$

Where: C = Concentration of PM_{10}s in air (kg/m^3)
E = PM10 emission rate ($kg/sec/m^2$)
X = Distance from upwind to downwind edge of the box (m)
H = Mixing height of the box (m)
u = Windspeed (m/sec) across the box

The values of these parameters were derived as follows:

E The emission rate was calculated as described above.

X The "box" in which riding occurs was assumed to be square. Based on the assumed area of $2E+05m^2$, this corresponds to a length of approximately 450 m.

H The mixing height of the box is a function of distance from the source and turbulence of the air which, in turn , is a function of the roughness of the terrain. The value of H at the upwind edge of the site is assumed to be zero. At the downwind edge, the value of H was calculated from the following equation:

$$X = 6.25Zo\ [(H/Zo) - 1.58(H/Zo) + 1.58]$$

Where: X = Upwind to downwind distance (m)
Zo = Roughness height (m)

As noted above, X is assumed to be about 450 m. The roughness height is a function of the height of natural and man-made objects (trees, buildings, etc.) in the vicinity of the source. Areas at the Rico Site, where dirt-bike riding is assumed to take place, are devoid of tall buildings and have very few trees. The value of Zo was, therefore, estimated to be 4 cm (0.04 m) based on the graph presented in Figure 3-6 Cowherd et al. (1985).

u The average wind speed was assumed to be 3.6 m/sec, based on the value used at Anaconda (CDM, 1995).